

**PENETRATION RESISTANCE AND AGRONOMIC CHARACTERISTICS OF SOYBEAN  
AFFECTED BY SOIL MANAGEMENT AND SOWING SPEED SYSTEMS**

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**ABSTRACT:** With the short period of the sowing process, we observed an increase in the seeder speed set in several soil management systems that may result in decreased soybean yield and problems with penetration resistance. We aimed to assess the penetration resistance (PR) and agronomic characteristics of soybean on soil tillage and sowing speed. The randomized block design in split plot with four replications was used. The treatments consisted of six management systems, applied to the plots: no tillage (NT), no tillage and chiseling (NTc), no tillage and cross chiseling (NTcc), conventional tillage (CT), reduced tillage (RT) and conservation tillage (CsT) and four speeds, (4.6; 5.5; 7.3 and 7.8 km h<sup>-1</sup>) applied in the subplot at the time of soybean seeding. We observed in the deep layers 0.0 – 0.10; 0.10 – 0.20 and 0.20 – 0.30 m significant effect of tillage systems on the PR of the soil. The NT system showed the highest value of PR compared to other management systems studied. In the NT should be used sowing speeds above 5.5 km h<sup>-1</sup> to decrease the compression. Low speeds favor higher yield by improving pods per plant. Speeds in the working range (5-7 km h<sup>-1</sup>) promote higher productivity by improving the number of pods per plant, and provide better stand.

**KEY WORDS:** agricultural mechanization, no tillage, yield.

**INTRODUCTION**

The competitiveness and sustainability of agricultural production systems have led farmers to seek ways to enhance their crops, using preparation systems that harm less the soil, due to the erosion and degradation, promoted by periodical preparation (BELLÉ et al., 2014). Due to the increasing use by farmers of systems that have less mobilization, such as no tillage (NT), many areas began to show compaction problems associated with no soil inversion (MUZARANA et al., 2011), which has resulted in productivity decrease (ROBOREDO et al., 2010).

Systems with minimum tillage, such as NT, showed higher grain yield when compared to minimum tillage and conventional tillage (PEREIRA et al., 2011). The fact that the highest grain yield in NT may be related to the speed of seedling emergence that is superior when compared to the conventional system, and may be associated with the lack of vegetation, so sealing or superficial crusting effect may occur (LIMA et al., 2010).

MUZARANA et al. (2011) when evaluated tillage systems in Oxisol, observed that the bulk density was lower in tillage systems with greater mobilization, showing the lowest values for the NT, which has been adopted to replace conventional tillage in order to mitigate soil degradation problems. The NT has shown over the years problems of subsurface compaction due to minimum soil inversion, which is restricted to row sowing (ROSA et al., 2011). In this context, the determination of compression is essential in scientific studies that evaluate the machine-soil-plant relation (LIMA et al., 2013). The penetration resistance is an attribute that allows to view the areas that show greater or lesser easiness of root penetration (SILVEIRA et al., 2010), and it is important its knowledge for proper management.

Thus, management systems can contribute to improving the soil quality by the increase of organic matter and better structure, and other factors that contribute to greater infiltration of water and air, greater availability of nutrients and better plant development. The study of sowing speed is

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justified by the fact that these can influence the final plant stand and even productivity. This demonstrates and justifies the need for studies of the interaction of soil management and sowing speed systems.

Therefore, we aimed to evaluate the soil management and sowing speed of soybean, and their effects on agronomic components and penetration resistance.

## MATERIAL AND METHODS

The study was carried out at the Experimental Farm of Agricultural Sciences - FAECA, of the Federal University of Grande Dourados - UFGD located in the municipality of Dourados, MS, Brazil. The site is located at latitude 22°14'S, longitude 54°59'W and altitude of 434 m. The climate is Cwa, according to the Köppen classification. The soil of the area is Dystroferic Oxisol (EMBRAPA, 2013), clay texture (62.23% of clay, 20.43% of silt, 17.34% of sand). The average moisture of the soil profile at the time of collection of the penetration resistance was 15.67%.

In the plots preparation of the soil management systems for the experiment in the 2013/2014 harvest, we used: Chisel plow of five shank, with narrow tip of 0.08 m of width and 0.35 m of depth (chiseling treatment); moldboard plow cut with 0.40 cm of depth (conventional preparation); off-set disk harrow with 20 disks of 0.51 m of diameter (20") in each section, at the front section cut discs and plain discs at the rear, at a depth of 0.15 m (conventional, reduced and cross chiseling preparation). For the preparation operations, we used a tractor with 67.71 kW (92 hp) of nominal power in the engine at a rotation of 2400 rpm, and a tractor with 89.79 kW (122 hp) of nominal power in the engine at a rotation of 2200 rpm in the chiseling operation.

The seeder-fertilizer was used with pneumatic system of seeds distribution, shank furrow for fertilizer, with seven rows spaced 0.45 m, doser fertilizer of helicoid type, discs for 60 holes seeds, and dual wheels (V) angulated for compression. The seeder was set to distribute 16 seeds per meter, of the VTOP cultivar (RR), with 99% of purity and 80% of germination at a depth of 0.05 m.

The seeds were treated with insecticide, 125g of Thiamethoxam per 100 kg of seeds. The inoculation was carried out directly via seed, using the peat inoculant with the *Bradyrhizobium elkanii* SEMIA 587 strain, in bacterial population of  $3.0 \times 10^9$  cels  $g^{-1}$ , according to the standard method. In the fertilization, we used the 0-20-20 formulated in the regulation of 300 kg  $ha^{-1}$ . The area was previously desiccated with mechanized application of glyphosate-based herbicides (3L  $ha^{-1}$ ) and 2.4 D (0,8 L  $ha^{-1}$ ). During the harvest, the pest control in the crop was carried out with Flubendiamide 0.3 L  $ha^{-1}$ , Methomyl 0.5 L  $ha^{-1}$  and disease using a combination of Azoxystrobin + Cyproconazole 0.3 L  $ha^{-1}$  and Pyraclostrobin + Epoxiconazole 0, 5 L  $ha^{-1}$ .

We used the randomized blocks design in a split plot with four replications. The treatments consisted of six management systems, applied in the plots (Table 1). The speeds applied in the subplot at the time of soybean planting, defined by the tractor speed scaling, were 4.6; 5.5; 7.3 and 7.8 km  $h^{-1}$ .

TABLE 1. Management systems (plots) with their respective operations and depths.

Treatments	Operations number	Depth (m)
NT	Without preparation	---
NTc	One chiseling	0.35 m
NTcc	Two chiseling and one harrowing	0.35 and 0.15 m
CT	One plowing and two harrowing	0.35 and 0.15 m
RT	One harrowing	0.15 m
CsT	One chiseling and one harrowing	0.35 and 0.15 m

no tillage (NT); no tillage and chiseling (NTc); no tillage cross chiseling (NTcc); conventional tillage (CT); reduced tillage (RT); and conservation tillage (CsT).

Each plot occupied an area of 15 m of wide and 19 m of length (285 m<sup>2</sup>). In the longitudinal direction between the plots, a space of 12 m was reserved for the maneuvers, machinery traffic and stabilization of the sets.

The soil penetration resistance data (PR) were collected, in a point in the central region of each subplot by an impact penetrometer, with the following characteristics: mass of 4 kg with impact in free fall course of 0.40 m; cone with 0.0128 m of diameter and solid angle of 30°; and shank with a diameter of approximately 0.01 m. The PR data were recorded up to the depth of 0.60 m and converted to MPa.

The stand of plants was obtained from the number of emerged seedlings count after the stabilization, in a meter in the central row of each subplot. The number of pods per plant was obtained by direct counting in three plants per plot, obtaining the final average.

The plants were harvested in one meter in the central row to obtain the productivity, which were threshed and their masses measured separately by subplot and their values corrected to 13% of moisture, using the mass formula of dry product produced per wet product unit, which consists of 100 minus the initial humidity divided by 100 minus the final moisture, with the result of this division, this is multiplied by the mass of the initial grains.

The data analysis was carried out by the variance analysis and later, when significant, with the Tukey test at 5% probability to compare averages. The data that were significant in the F test for sowing speed were applied polynomial regression analysis. The Assistat software Version 7.7 Beta (SILVA & AZEVEDO, 2002) was used.

## RESULTS AND DISCUSSION

In the depth layers of 0.0 – 0.10; 0.10 – 0.20 and 0.20 – 0.30 m occurred significant effect of management systems on the soil PR (Table 2). In these layers, the NT system showed the highest PR value in comparison to the other management systems studied. In the depth layers of 0.30 - 0.40 m occurred significant effect of management systems studied on soil PR, being the NTc and NTcc systems with the highest value (Table 2). According to LIMA et al., (2010), values from 1.9 MPa can affect the plants height in the soybean crop, a value below the ones found in this study, especially in the depth layers of 0.20 – 0.30 and 0.30 – 0.40 m. In general, when observing the PR values in the studied layers, for the NT, it is notorious that they are above of the considered critical to the development of the root system, it may be justified because it is a system with a minimum tillage, particularly in the depth layer of 0.20 to 0.30 m. CHEBURIN et al. (2011) found similar results and when they studied the soil PR variability, they found values higher than the considered critical to a depth of 0.40 m; and also by DRESCHER et al. (2012). In the depth layers of 0.40 – 0.50 and 0.50 – 0.60 m, there was no significant effect on any of the management systems studied on soil PR, and also the presence of higher values, because they are depths that do not have any type of tillage.

TABLE 2. Variance analysis and average tests for the soil penetration resistance (MPa).

	Layers (m)					
	0.0-0.10	0.10-0.20	0.20-0.30	0.30-0.40	0.40-0.50	0.50-0.60
Management (M)						
NT	2.23a	4.85 a	5.86 a	4.39 a	4.81	5.10
NTc	1.39 b	1.98 b	2.61 b	4.05 ab	5.06	5.61
NTcc	1.22 b	1.94 b	3.08 b	4.17 a	5.02	6.24
CsT	1.26 b	1.94 b	2.74 b	3.41 ab	4.60	5.99
RT	1.35 b	2.23 b	3.20 b	3.80 ab	5.10	5.91
CT	1.05 b	1.86 b	2.49 b	2.91 b	3.80	4.90
F test						
Management	17.27 **	23.88 **	22.88 **	4.23 *	1.67 <sup>NS</sup>	2.05 <sup>NS</sup>
Speed (S)	0.89 <sup>NS</sup>	3.67 *	3.09 *	4.53 **	13.59 **	9.08 **
MxS	1.93 *	1.59 <sup>NS</sup>	1.24 <sup>NS</sup>	1.35 <sup>NS</sup>	1.38 <sup>NS</sup>	1.04 <sup>NS</sup>
C.V. M (%)	28.22	38.96	31.86	27.95	32.39	26.27
C.V. S (%)	25.15	24.32	26.52	30.75	23.17	22.23

<sup>NS</sup>: not significant ( $p > 0.05$ ); \*: significant ( $p > 0.05$ ); \*\*: significant ( $p > 0.01$ ); C.V.: coefficient of variation

No tillage (NT); No tillage and chiseling (NTc); no tillage cross chiseling (NTcc); conventional tillage (CT); reduced tillage (RT); and conservation tillage (CsT). Lowercase letters in the same column and equal, do not differ from each other by the Tukey test at 5% probability.

In the depth layer of 0.0-0.10 m there was not significant effect of the studied speeds on soil PR (Table 2), but there was effect in the interaction M (management) x S (speed), (Table 3). In the depth layers of 0.10-0.20; 0.20-0.30; 0.30-0.40; 0.40-0.50 and 0.50-0.60 m there was significant effect of the studied speeds on soil PR, and the speed of 4.6 km h<sup>-1</sup> showed the highest PR value because it is the lowest speed and the highest time compression. The lower PR values were observed at the speed of 7.8 km h<sup>-1</sup>, and may be justified by lower time compression (Figure 1). The regression model adjusted to the PR indicates that the speed increase reduces the PR in the soil.

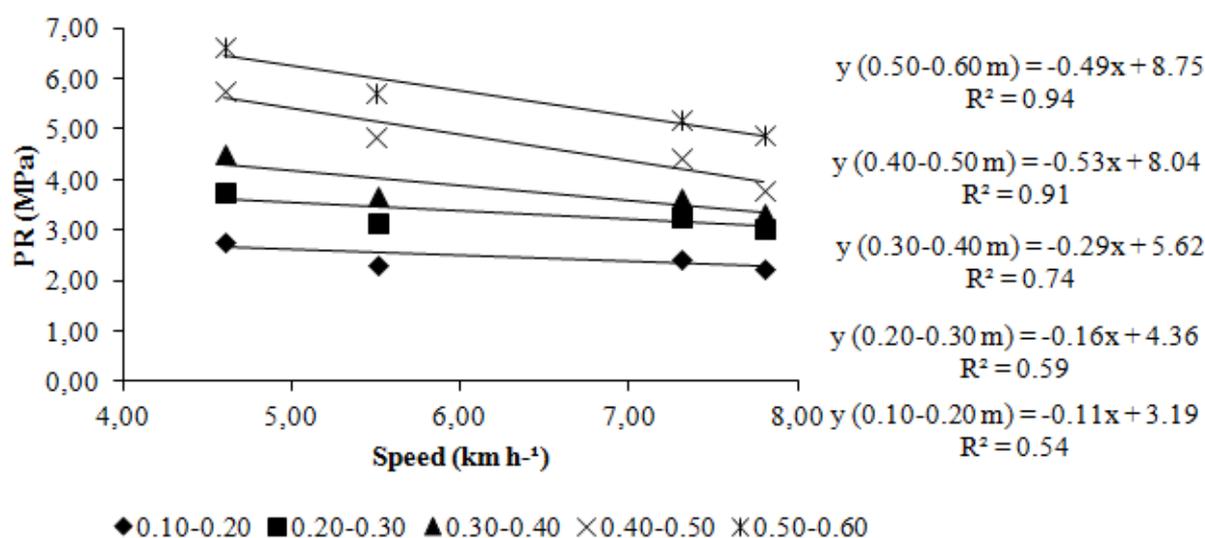


FIGURE 1. Penetration resistance (MPa) per layer depending on displacement speed.

We observed in the speeds of 4.6 and 7.8 km h<sup>-1</sup> the highest values of PR in the NT system (Table 3), and which can be justified by a system that has undergone a minimum tillage. This effect provided a quadratic adjust to the regression model for the speeds in NT, which was the only system with significant response for the speed, indicating that in the superficial layer, both the lower and higher speeds increased the PR (Figure 2). This fact is associated with greater time compression in the lower speeds, and to the increase of slip, with the increase of speed. In the speeds of 5.5 and 7.3

km h<sup>-1</sup> occurred significant effect on the soil PR and we observed the lowest values of soil PR for the CT system, which can be justified by the management system that had the most soil tillage.

TABLE 3. Unfolding of the management x speed interaction for soil penetration resistance (MPa) in the layer of 0.00 – 0.10m.

Managements	Speeds (km h <sup>-1</sup> )			
	4.6	5.5	7.3	7.8
	0.0-0.10 m			
NT	2.91 a	1.90 a	1.90 a	2.24 a
NTc	1.39 b	1.73 ab	1.22 ab	1.22 b
NTcc	1.22 b	1.22 ab	1.22 ab	1.22 b
CsT	1.22 b	1.39 ab	1.39 ab	1.05 b
RT	1.39 b	1.39 ab	1.39 ab	1.22 b
CT	0.88 b	1.05 b	1.05 b	1.22 b

Averages followed by the same letter, lowercase in columns do not differ from each other by Tukey test at 5% probability of error. No tillage (NT); No tillage and chiseling (NTc); no tillage cross chiseling (NTcc); conventional tillage (CT); reduced tillage (RT); and conservation tillage (CsT).

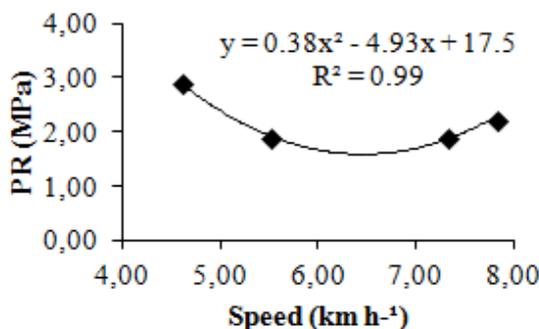


FIGURE 2. Penetration resistance (MPa) in the layer of 0.00-0.10 m for the no tillage system (NT) depending on the displacement speed.

For the agronomic components, the number of pods per plant showed significant effect of the managements versus sowing speeds interaction (Table 4). For the plant stand and grain yield there was no significant effect on soil management systems (Table 4), which may be attributed to the fact that is the first year of soil management systems, and still there is effect of the preparations which occurred for the implementation of the experimental area, but there was effect for the displacement speed (Table 4). PEREIRA et al. (2011) confirm that for soil management systems (conventional tillage, reduced tillage and no tillage) after five years of cultivation, showed no difference to the stand of soybeans and productivity. JASPER et al. (2011) state that the sowing speed (4, 6, 8, 10 and 12 km h<sup>-1</sup>) do not affect the plants population, whether for pneumatic doser or horizontal disc, which contradicts this study.

TABLE 4. Summary of the analysis of variance values and the average test for pods per plant, shoot dry matter and grain yield.

Factor	Stand (plants per meter)	Pods per plant	Productivity (kg ha <sup>-1</sup> )
Management (M)			
NT	9.44	38.64 a	2658.85
NTc	10.87	32.45 b	2555.82
NTcc	11.75	34.93 ab	2626.96
CsT	9.75	34.70 ab	2739.87
RT	10.25	31.27 b	2702.26
CT	10.25	38.68 a	2658.99
F test			
M	2.12 <sup>NS</sup>	7.64 **	0.22 <sup>NS</sup>
Speeds (S)	5.23 **	10.97 **	4.92 **
MxS	0.97 <sup>NS</sup>	3.97 **	1.77 <sup>NS</sup>
C.V. M (%)	21.78	12.66	20.24
C.V. S (%)	21.70	16.87	20.27

<sup>NS</sup>: not significant ( $p>0.05$ ); \*: significant ( $p>0.05$ ); \*\*: significant ( $p>0.01$ ); C.V: coefficient of variation. No tillage (NT); No tillage and chiseling (NTc); no tillage cross chiseling (NTcc); conventional tillage (CT); reduced tillage (RT); and conservation tillage (CsT). Averages followed by the same letter, lowercase in columns do not differ from each other by Tukey test at 5% probability of error.

The sowing speed influenced the plants stand, being better at the speed of 5.5 km h<sup>-1</sup> with 11.91 plants per meter, and the others: 4.6; 7.3 and 7.8 km h<sup>-1</sup> with 10.21; 9.58 and 9.83 plants per meter, respectively (Table 4 and Figure 3), which resulted in a quadratic adjust model in the regression.

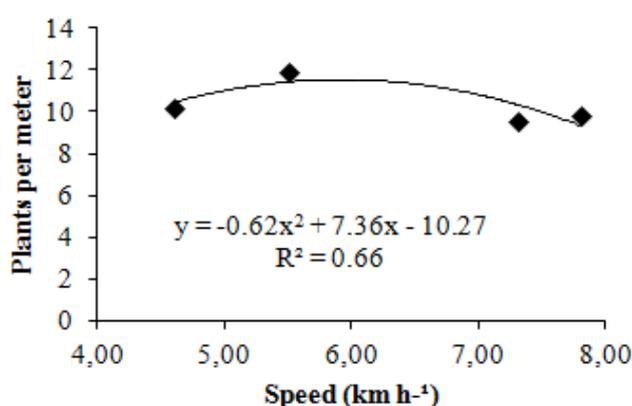


FIGURE 3. Plants stand regression per meter depending on displacement speed.

In the unfolding of the interaction of management versus sowing speed, for the amount of pods per plants, we observed that in the speed of 4.6 and 7.3 km h<sup>-1</sup> there was no significant effect on the studied management systems (Table 5). In the speed of 5.5 km h<sup>-1</sup>, the NT showed the highest value of pods per plant, while the conventional tillage the lowest value. This fact suggests negative effect of excessive mobilization caused by the plow and the grid in conventional tillage. However, in the speed of 7.8 km h<sup>-1</sup> the CT management system showed the highest value of pods per plant, but did not differ from the NT system. JASPER et al. (2011) found no effect on the yield of soybean components when the sowing speed varied from 4 to 12 km h<sup>-1</sup>, which was not verified in this study.

Only in the NT, NTc, NTcc management systems there was significant effect on the studied speed, and the speed of 5.5 km h<sup>-1</sup> showed the highest value of pods per plant, resulting in a quadratic adjust model in the regression, with the lowest and highest speeds decreasing the number of pods per plant (Figure 4). Therefore, the speeds over the working range (5 to 7 km h<sup>-1</sup>) reduce the

amount of pods per plant. Also, LUDWIG et al. (2011) evaluated soybean crops and plants population, and found that the number of pods per plant is reduced with the increase number of plants per area, also observed by MAUAD et al. (2010) when evaluated the stand with 10, 12, 14, 16 and 18 plants per meter. What differs from this study, in which in the highest plants stand had the highest amount of pod in the speed of 5.5 km h<sup>-1</sup>. LUDWIG et al. (2011) explain that there is compensation between the number of pods per plant and the number of plants, but it did not occur in this study.

TABLE 5. Unfolding of the management x speed interaction for pods per plant.

Managements	Speeds (km h <sup>-1</sup> )			
	4,6	5,5	7,3	7,8
NT	32.58 a	53.17 a	35.67 a	33.17 ab
NTc	33.17 a	40.25 bc	32.33 a	24.08 b
NTcc	36.91 a	45.25 ab	31.67 a	25.92 b
CsT	40.33 a	34.42 bc	29.25 a	34.83 ab
RT	34.58 a	34.08 bc	30.00 a	26.42 b
CT	42.58 a	33.00 c	35.33 a	43.83 a

Averages followed by the same letter, lowercase in columns do not differ from each other by Tukey test at 5% probability of error.

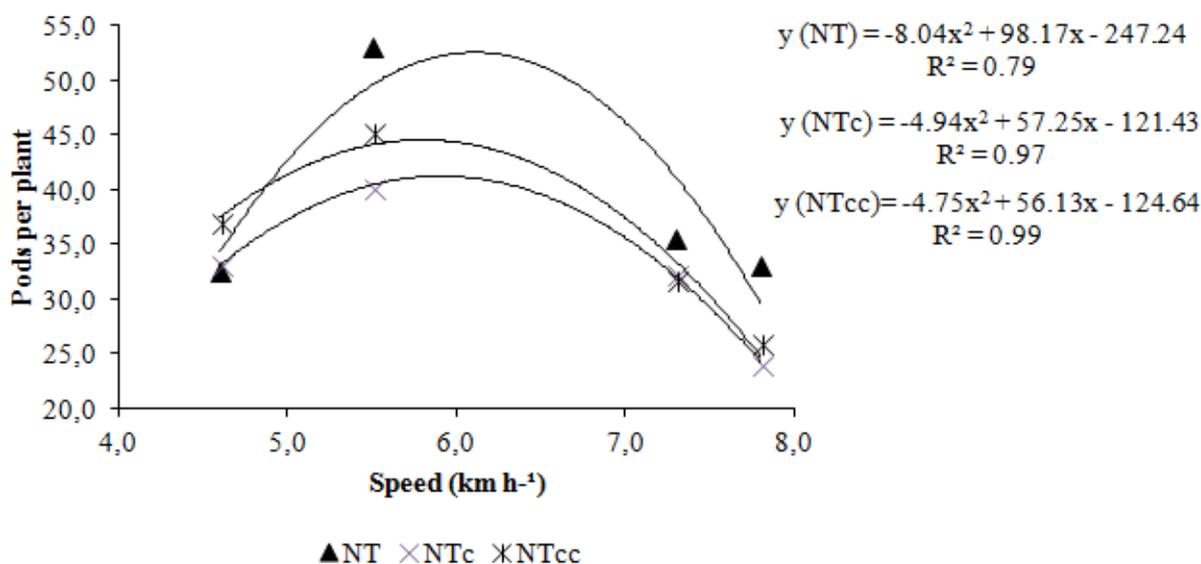


FIGURE 4. Number of pods per plant for no tillage (NT), no tillage chiseled (NTc), and no tillage cross chiseled (NTcc), depending on the displacement speed.

The sowing speed influenced the grain yield, and it is higher in the speed of 5.5 km h<sup>-1</sup>, which provided a quadratic adjust to the regression model, (Figure 5). This fact may be related to the highest stand of plant in this speed (Figure 3), and according to LUDWIG et al. (2011) the highest productivities are reached when there is the highest amount of pods per m<sup>2</sup>. What was found in this study by the highest amount of pod in this speed.

As the soybean crop has the capacity to adapt when the stand variations, and the fact that the difference between the stands (Figure 3) was less than 25%, we expected a compensation (LUDWIG et al., 2011) by the highest pods production, and consequently to maintain the closest productivity, regardless of speed, which has not happened (Figure 5).

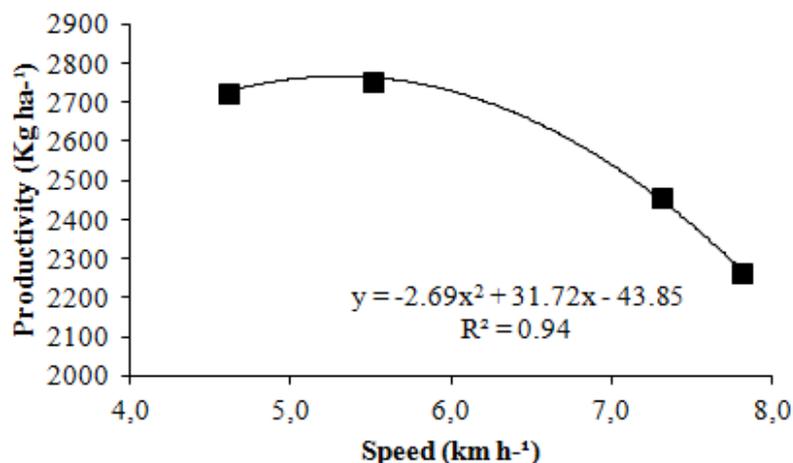


FIGURE 5. Grain yield (kg ha<sup>-1</sup>) depending on the displacement speed.

## CONCLUSIONS

The no tillage system showed the highest value of penetration resistance. In the no tillage system the sowing speed of 5.5 km h<sup>-1</sup> should be used to decrease the soil compaction.

Soil management systems that use equipment with shank to preparation reduce the penetration resistance, similar to the conventional tillage.

Speeds on the working range (5 to 7 km h<sup>-1</sup>) favor higher yields, by improving the number of pods per plant, and do not affect the stand.

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