

Furrow depth, soil disturbance area and draft force of a seeder-fertilizer at different seeding speeds

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ABSTRACT

The aim of this study was to evaluate the furrow depth, the area of soil disturbance and the draft force required for a precision seeder-fertilizer as a function of seeding speed in a no till system for corn production. The experiment was conducted in a 4³ factorial randomized block design with four replications, consisting of four forward speeds obtained by changing gears and three tractor's engine rotation speeds. During seeding, the operating speed, engine rotation speed and draft force on the drawbar were measured. After seeding, furrow depth and area of soil disturbed were assessed. The results showed that: the furrow depth was influenced by the increase in the operating speed; the area of soil disturbed increased by 41% with increasing operating speed, the average drawbar draft required per seeding line and per area of soil disturbed decreased with increasing speed; and the average drawbar draft per furrow depth increased with the operating speed.

Key words: No till system, energy demand, agricultural mechanization.

RESUMO

Profundidade de sulco, área de solo mobilizada e força de tração de uma semeadora-adubadora em razão da velocidade de deslocamento

Este trabalho teve por objetivo avaliar a profundidade de sulco, área de solo mobilizada e a força de tração solicitada por uma semeadora-adubadora de precisão em sistema de plantio direto na cultura do milho, em razão da velocidade de deslocamento. O delineamento experimental foi em blocos ao acaso, com quatro repetições em arranjo fatorial 4 x 3, com 12 tratamentos, constituídos de quatro velocidades de deslocamento, obtidas pelos escalonamentos de marchas e de três rotações do motor do trator. Durante a semeadura, monitoraram-se a velocidade de operação, a rotação do motor e a força de tração na barra. Após a semeadura, foram avaliadas a profundidade do sulco e a área mobilizada de solo. Os resultados mostraram que: a profundidade do sulco foi influenciada pelo aumento na velocidade de operação; a área mobilizada de solo aumentou em 41% com a elevação da velocidade de operação; o requerimento de força na barra de tração, média, por linha de semeadura e por área mobilizada de solo diminuiu com o aumento da velocidade; e a força média na barra de tração por profundidade do sulco aumentou com o incremento da velocidade de operação.

Palavras-chave: Plantio direto, demanda energética, mecanização agrícola.

Recebido para publicação em junho de 2010 e aprovado em maio de 2011

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INTRODUCTION

The energy consumption on the implementation of any crop, cultural practices and grain harvesting is crucial for the farmer. Optimizing field operations and, thus, lowering energy consumption by the correct use of farm machinery, increases profitability at the end of each season. However, because of direct seeding systems, seed drills had their manufacturing process changed, making them robust, heavy and with soil-engaging components capable of breaking compacted soil layers caused by equipment traffic on the field, and hence newer seeders require tractors to have more traction power to pull them.

Cepik *et al.* (2010) discuss that farmers should consider the use of shank-type furrow openers for fertilizer application in compacted soils or compaction-prone areas. In direct seeding, nutrients tend to concentrate on the soil surface. Shank furrow openers allow fertilizer placement at greater depths, which can induce roots to grow deeper into the soil and, thereby, reduce compaction effects on plant growth. However, some studies have shown that the use of shank openers, instead of double discs, increases the furrow depth and the area of soil disturbance (Mion & Benez, 2008), the draft force required and fuel consumption (Silva, 2003).

The draft force required for the operation of large grain seeders (precision seeders) in the horizontal travel direction, including the machine's rolling resistance, in a good seedbed, ranges from 0.9 kN ± 25% per line, for seeding only, and 3.4 kN ± 35% per line, for seeding, fertilizer and herbicide application (ASAE, 1999).

Silveira *et al.* (2005), working with two seeding depths and different operating speeds, found that increasing the speed from 5.24 to 7.09 km h⁻¹, the draft force increased by 12.08 and 3.70% at the seeding depths of 1.97 and 2.68 cm, respectively. Furlani *et al.* (2008), studying the performance of a precision seeder-fertilizer as a function of type of tillage, forward speeds and tire inflation pressure, also observed that seeding at 3.4 km h⁻¹ had lower draft and drawbar power requirements compared with the operating speed of 6.0 km h⁻¹.

Collins & Fowler (1996), studying planters with double disks and knife-type of furrow openers in a clay soil, recorded draft forces of 0.20 and 1.12 kN per line, respectively. These authors found that for speeds between 6.0 and 10.0 km h⁻¹ the drawbar draft force increased by 4% for each km h⁻¹ increase in speed and 20% for each centimeter increase in seeding depth, regardless of the type of furrow opener.

A study on energy demand in corn seeding, at different speeds and soil management systems (no till and chisel plowing), showed that the drawbar draft was not influenced by the soil preparation, but, while at the two lower speeds (4.4 and 6.1 km h⁻¹) the draft forces were

similar, at the highest speed (8.1 km h⁻¹), the difference was significant (Mahl *et al.*, 2004).

Modolo *et al.* (2005) found that the draft force required by a precision seeder fertilizer varied with the number of seed lines and the distribution of lines in the machine. The average drawbar draft force increased by 131.9% with the increase in the number of seed lines from one to five.

This study aimed to evaluate the furrow depth, the area of soil disturbed and the draft force of a precision seeder fertilizer as a function of seeding speed in a no till system for corn production.

MATERIAL AND METHODS

The experiment was conducted at the Experimental Field of Assis Gurgacz Foundation, Cascavel-PR, from September to November, 2006. The soil is classified as a heavy clay textured Oxisol (6.8% sand, 17.8% silt, and 75.4% clay). The area is located between coordinates 24°56'30" South latitude and 53°30'28" West longitude, average altitude of 760 m and slope between 0 and 3%. The experiment was arranged in a 4³ factorial randomized block design with four replications: 12 treatments consisting of four forward speeds (3.5, 4.0, 5.5, and 7.0 km h⁻¹) obtained by changing gears and three tractor's engine rotation speeds (1500, 1900 and 2100 rpm), totaling 48 experimental units.

The experiments were performed with a Tatu Marchesan PST³ trailing seeder fertilizer machine with six seed lines, BR 8.1 perforated horizontal plate seed metering devices (11 x 8 mm), with 28 slotted holes, 4.3 mm plain AM000 ring, 20" disc coulter, double discs for seed distribution, shank-type furrow openers (knives) for fertilizer and aligned dual-angled presswheels.

The tractor used to pull the planter was a FORD 7630, 4x2, with front wheel assist (FWA), 75.8 kW (103 hp) engine power at 2100 rpm and mass of 3580 kg without ballast and 6196 kg with maximum ballast. During the test, the tractor was equipped with maximum ballast, i.e., front ballast on tires and wheels.

AG 405 corn hybrid seeds, 100% purity and 98% minimum germination, according to company data (*Agroceres*) were used in the trials. An 8-20-20 NPK fertilizer was used at the recommended rate of 330 kg ha⁻¹. Crop residue desiccation (rye) was carried out by using 1.8 L ha⁻¹ glyphosate.

Data on furrow depth was randomly collected by inserting a cm-graded ruler into the furrow and taking 15 readings per seed line. For the area of soil disturbed, we used an aluminum profilometer with vertical cm-graded rulers arranged every 2 cm in the transverse direction. The area of soil disturbed was determined by the equation:

$$A_m = \sum (P_N - P_S) e \quad (\text{eq. 1})$$

Where,

A_m = disturbed area (m²);

P_N = height of the natural soil surface profile at each point of the profilometer (m);

P_S = height of the final soil surface profile at each point of the profilometer (m), after

seeding; and

e = spacing between the vertical rules (m).

A data acquisition system — a *Campbell Scientific* CR23X datalogger was used to continuously record and store the signals generated by the transducers (load cell, radar and infrared optical sensor) installed on the motor-mechanized assembly.

The drawbar draft required to pull the seeder-fertilizer, the travel speed and the rotation of the motor shaft were recorded. The drawbar draft required was recorded by a SODMEX N400 load cell, with 2.156 mVV⁻¹ sensitivity, coupled between the tractor and the seeder. The pin that holds the drawbar was removed so that it was free and all the draft force required by the seeder was applied to the load cell. The average draft force was determined by equation 2.

$$F_m = \frac{\sum_{i=1}^n F_i}{n} * 0,0098 \quad (\text{eq. 2})$$

where:

F_m = average draft force (kN);

F_i = instant draft force (kgf);

n = number of recorded data, and

0.0098 = conversion factor for kN.

The travel speed was recorded by a *DICKEY-john* Radar Velocity Sensor - DjRVS, with errors of less than $\pm 3\%$ for speeds from 3.2 to 7.08 km h⁻¹. The rotation of the motor shaft was recorded by an infrared optical sensor and a 60-toothed gearwheel which gave out 60 pulses per revolution. The wheel was used to determine the rotation of the motor shaft and was coupled to the power take-off (PTO) of the tractor, along with the infrared optical sensor. Using the tractor manufacturer's catalog, we determined the transmission ratio between the rotation of the motor shaft and the PTO rotation. Knowing the transmission ratio and the number of pulses generated by the toothed gearwheel attached to the PTO, we determined the rotation of the tractor power take-off (PTO) and, therefore, the rotation of the engine.

The results were examined by the analysis of variance, and when the interaction between the factors operating speed and engine rotation was significant, the regression analysis was performed. The statistical analysis was performed using the software SAEG 9.1 (UFV, 2007).

RESULTS AND DISCUSSION

The average biomass in the experimental area was 2.41 ton ha⁻¹. The average water content and density of the soil at a depth of 0-0.10 m were 0.32 kg kg⁻¹ and 1.05 Mg m⁻³, respectively, and, from 0.10 to 0.20 m, the mean values were 0.26 kg kg⁻¹ and 1.11 Mg m⁻³. The highest value recorded for soil resistance to penetration (MPa) in the experimental area was 1.36 MPa at a depth of 0-0.10 m, measured by a PNT-2000 penetrometer.

Because the t -test ($P > 0.05$) showed that only the regression coefficient of the variable operating speed was significant, we removed the variable engine speed from the regression model, generating equations using only the variable operating speed.

Furrow depth for fertilizer placement

Figure 1 shows the results of regression analysis between furrow depth for fertilizer placement and operating speed, with both showing linear trend. The coefficient of determination of the regression analysis between the furrow depth for fertilizer and the operating speed of the mechanized assembly was 0.94, meaning, therefore, that 94% of the variation in furrow depth was explained by the change in speed, with the remainder owing to other factors inherent to operating speed.

The shank opener operated at the proper depth (0.10 m), showing little variation. At the highest speed (V4), the furrow depth was the shallowest (0.0929 m), while at the slowest speed (V1), the furrow depth was the deepest (0.1114 m). Deeper furrows at lower speeds were also

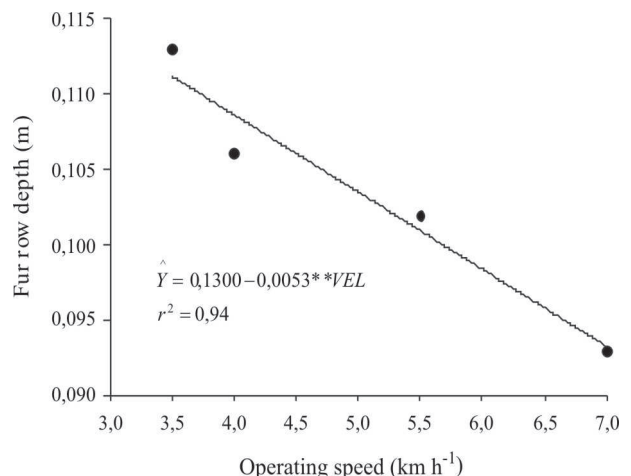


Figure 1. Fertilizer furrow depth as a function of the operating speed of the mechanized assembly.

reported by Casão Junior *et al.* (2000) and Mahl *et al.* (2004).

The decrease in furrow depth for fertilizer deposition with the increase in operating speed can be attributed to knife-type openers. These openers tend to move closer to the surface, even when adjusted to place the fertilizer to predetermined depths. Soil roughness, soil moisture and resistance to penetration, among other factors, may affect this variable.

Area of soil disturbed

Figure 2 shows the results of regression analysis between area of soil disturbed and operating speed. The fitted model, considering the different speeds, showed a linear trend with determination coefficient of 0.92. We recorded for each km h⁻¹ increase in the operating speed of the mechanized assembly an increase of 0.0008 m² in the area of soil disturbed, which was lower at 3.5 km h⁻¹ (0.0069 m²) and higher at 7.0 km h⁻¹ (0.0097 m²).

Increasing the operating speed from 3.5 to 7.0 km h⁻¹ caused a 41% increase in area of soil disturbed per line. This trend was not observed by Silva *et al.* (2001), when evaluating the performance of a seeder-fertilizer in no-till corn sowing in a clay soil.

Drawbar draft requirement

Observing Figure 3, we notice a clear decreasing linear trend for drawbar draft requirement with increasing speed of operation. When the speed increased from 3.5 to 7 km h⁻¹, the drawbar draft requirement decreased by 9%, which must be considered for purposes of sizing the assembly. This result may be attributed to the lowest furrow depth found at the highest operating speed (Figure 1).

Similarly, reduction in drawbar draft requirement due to increased speed was reported by Furlani *et al.* (2007) and Santos *et al.* (2008). Conversely, Bortolotto *et*

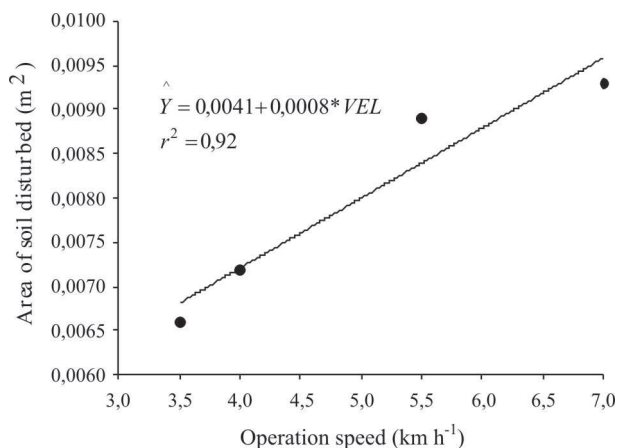


Figure 2. Area of soil disturbed as a function of the operating speed of the mechanized assembly.

al. (2006) found 2.5% increase in drawbar draft when the operating speed increased from 4.7 to 7.2 km h⁻¹, in a no-till system in an Oxisol. But, Modolo *et al.* (2004), Trintin *et al.* (2005) and Furlani *et al.* (2005) found no effects of increased operating speed on average values of drawbar draft.

Drawbar draft requirement per seeding line

The estimates of regression analysis for drawbar draft required per seeding line as a function of operating speed is shown in Figure 4. The fitted model for the variable showed a decreasing linear trend with increasing speed and determination coefficient of 0.87. For each unit increase in speed of the mechanized assembly, the average draft on the drawbar per seeding line decreased by 0.0533 kN.

The lowest operating speed required the highest draft force per line (2.61 kN), whereas the highest speed required the lowest draft force (2.42 kN), resulting in a reduction of 9.1%. Bortolotto *et al.* (2005) evaluated the energy demand

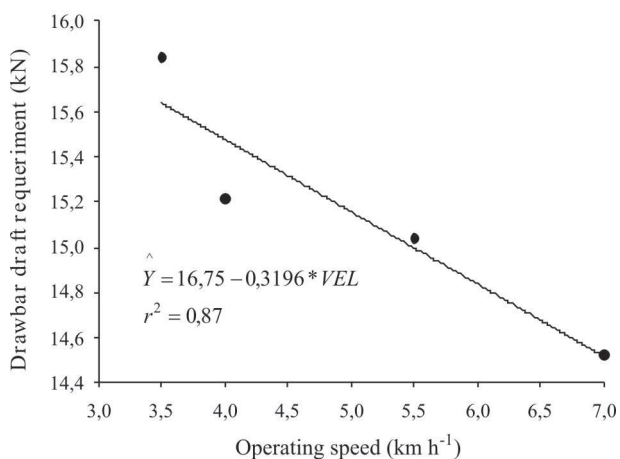


Figure 3. Drawbar draft requirement as a function of the operating speed of the mechanized assembly.

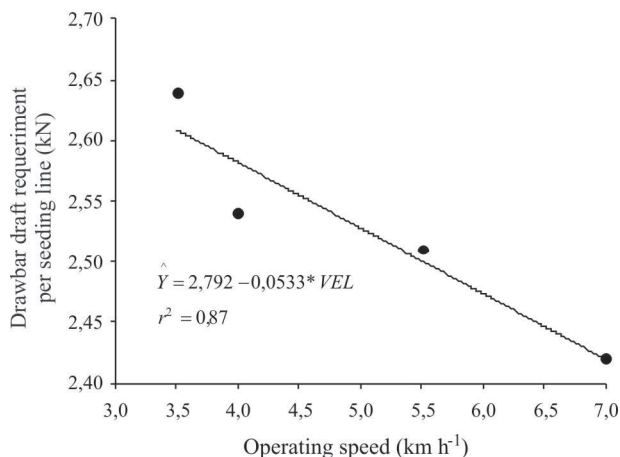


Figure 4. Drawbar draft requirement per seeding line as a function of the operating speed of the mechanized assembly.

of a PST³ Supreme seeder-fertilizer with eight seeding lines at different travel speeds and types of vegetation. These authors found draft force per seeding line equivalent to 1.62, 1.64, and 1.76 kN when working with speeds similar to those used in this work.

Studying the energy demand of a seed drill, Modolo *et al.* (2005) found a 126.41% increase in the draft force required when increasing the seeding lines from one to five, with values below those recorded in this work. The draft force requirement per seeding line (kN) recorded in this experiment, for seeding and fertilization operations, are within the range recommended by ASAE (1999).

Drawbar draft requirement per furrow depth

Figure 5 shows the results of regression analysis for drawbar draft required per furrow depth. The coefficient of determination was 0.95. For each km h⁻¹ increase in the operating speed of the mechanized assembly there was an increase of 0.8146 kN m⁻¹ on the drawbar draft requirement per furrow depth.

The drawbar draft requirement per furrow depth increased with the operating speed. However, while the depth was reduced with increasing speed, the draft force per furrow depth was increased. These results differ from those reported by Siqueira *et al.* (2001), in which increasing the operating speed did not increase drawbar draft requirement in relation to furrow depth. But, Mahl *et al.* (2004) found results similar to our findings when varying the operating speed.

Drawbar draft requirement per area of soil disturbed

In relation to drawbar draft requirement per area of soil disturbed for the factors studied, the linear regression showed significance for operating speed (Figure 6).

The coefficient of determination of this model was 0.91, and 9% of the variation in the drawbar draft requirement

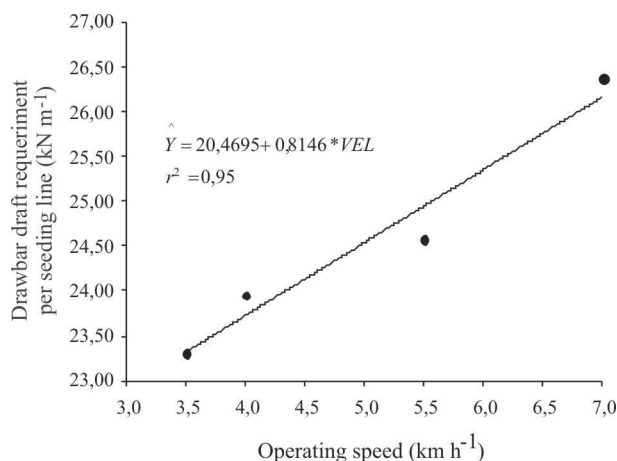


Figure 5. Drawbar draft requirement per furrow depth as a function of the operating speed of the mechanized assembly.

per area of soil disturbed could not be explained by the analysis. It was found that for each km h⁻¹ increase in the operating speed, the draft force per area of soil disturbed decreased by 294.94 kN m⁻².

The average values of the drawbar draft per area of soil disturbed at the tested speeds were 2508, 2360, 1918, and 1475 kN m⁻², from the lowest to the highest speed. These values are below those reported by Mahl *et al.* (2004), when evaluating the performance of a seeder-fertilizer in a no-till system for corn sowing, and above those obtained by Bortolotto *et al.* (2005).

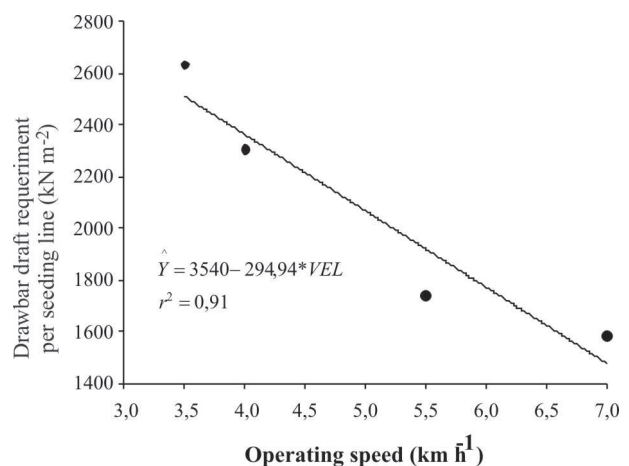


Figure 6. Drawbar draft requirement per area of soil disturbed as a function of the operating speed of the mechanized assembly.

CONCLUSION

The average drawbar draft requirement per seeding line and area of soil disturbed decreased with increasing speed, while the average drawbar draft per furrow depth increased with increasing operating speed.

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