

<http://dx.doi.org/10.15361/1984-5529.2015v43n3p221-225>

Disk harrow operational performance in three engine rotation speeds

Desempenho operacional de uma grade aradora em três rotações de trabalho do motor

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Recebido em: 09-09-2014; Aceito em: 16-03-2015

Abstract

Even with the current techniques of conservation tillage, mobilization is still a widely used practice, either in initial preparation as in reform of agricultural areas. In this context the harrows are widely used, mainly because of the good working capacity and high efficiency in tillage soil. Thus, this study aimed to evaluate the operating performance of a disk harrow in clay soil using different spins. The experiment was conducted at the Experimental Farm Lageado, belonging to the Faculty of Agricultural Sciences - UNESP Botucatu - SP. For accomplishment of the tillage was used a disk harrow, mark Tatu Marchesan model GAICR off-set, with a cutting width of 2.57 m and consists of 20 cut disks of 0,71 m (28 inches) spaced at 0.27 m. To exert traction the disk harrow was used of tires tractor John Deere brand, model JD6600 with power 91.48 kW (121 hp) engine. The used treatments were three engine revolutions, 157 rad s⁻¹ (1500 rpm), 189 rad s⁻¹ (1800 rpm) and 220 rad s⁻¹ (2100 rpm), and evaluated the working speeds achieved, effective field capacity, operational fuel consumption, working depth of the disk harrow, skating wheels of the tractor and drawbar force. The results indicated that most job rotation provided lower fuel consumption and greater field capacity. However, the increase in speed of work provided a reduction of working depth of the discs of the harrow.

Additional keywords: fuel consumption; soil preparation; velocity; working depth.

Resumo

Mesmo nos dias atuais com técnicas conservacionistas de preparo do solo, a mobilização ainda é uma prática muito utilizada, seja em preparo inicial, seja em reforma de áreas agrícolas. Nesse contexto, as grades agrícolas são muito utilizadas, principalmente por apresentarem boa capacidade de trabalho e elevado rendimento nos preparos de solo. Desta forma, o presente trabalho teve como objetivo avaliar o desempenho operacional de uma grade aradora em solo argiloso utilizando diferentes rotações de trabalho no motor. O experimento foi realizado na Fazenda Experimental Lageado, pertencente à Faculdade de Ciências Agrônômicas – UNESP de Botucatu – SP. Para a realização do preparo do solo, foi utilizada uma grade, marca Tatu Marchesan, modelo GAICR off-set, com largura de corte de 2,57 m e constituída por 20 discos recortados de 0,71 m (28 polegadas), espaçados de 0,27 m. Para tracionar a grade, foi utilizado trator de pneus marca John Deere, modelo JD6600, com potência de 91,48 kW (121 cv) no motor. Os tratamentos utilizados foram três rotações do motor, 157 rad s⁻¹ (1500 rpm), 189 rad s⁻¹ (1800 rpm) and 220 rad s⁻¹ (2100 rpm), sendo avaliados as velocidades de trabalho alcançadas, a capacidade de campo efetiva, o consumo operacional de combustível, a profundidade de trabalho da grade, a patinação dos rodados do trator, a força de tração requerida e a potência na barra de tração. Os resultados obtidos indicaram que a maior rotação de trabalho proporcionou menor consumo de combustível e maior capacidade de campo. Porém, o aumento da rotação de trabalho proporcionou redução da profundidade de trabalho dos discos da grade.

Palavras-chave adicionais: consumo de combustível; preparo de solo; profundidade de trabalho; velocidade de deslocamento.

Introduction

In modern agriculture, agricultural machines occupy a prominent place both in production costs composition, as on energy demand for agricultural operations. Machinery proper selection and correct

use are of fundamental interest to reduce agricultural machinery energy demand (Jasper & Silva, 2013). Among the different cropping systems, conservative and conventional, the conventional tillage system is one of the activities with higher energy costs in the grain production system (Sá et al., 2013).

In addition to tractor/implement set correct selection to perform the farming operation, it is essential that this is done at soil field capacity right time, with correct settings in engine speed, gearbox transmission ratio, tires inflation pressure and tractor ballasting (Serrano, 2007).

Frantz et al. (2014) states that transmission speed is performed by a set of elements that guarantees the engine power transfer to the hydraulic system, TDP and tractor driving wheels, with engine speed having direct relation with fuel consumption and power being available to the implement, favoring or limiting the operation to be performed quality.

According to Cortez et al. (2008), what basically affects fuel consumption in tillage equipment use is the increase in power consumption by increasing the working speed. Silveira et al. (2013) stated that within a same operating speed and varying the engine speed, there are significant increases in hourly fuel consumption, which range between 7-44%, from the lowest to the highest engine speed operation for sowing example. In general, Gamero et al. (1986) reported that in soil tillage operations, fuel consumption is about 30% of the hourly cost of an agricultural tractor.

In conventional operations, Stolf et al. (2010) reported that harrows are one of the most used implement class for tillage in the preparation for planting. Usable both in primary and in secondary preparation, the most commonly used justifications for soil preparation with this implement type is the weed control, plant residues management, soil aeration and porosity improvement, a good seedbed preparation and improving soil physical conditions.

In Brazil, among the operations of soil preparation included in sugar cane cultivation system, it is estimated that about one million hectares per year are mobilized with harrows for reed bed reform. Considering three harrowing per unit area, along with the harrowing sum carried out in areas cultivated with corn, it is equivalent to approximately 2.700 turns around the Earth, demonstrating harrows importance

in tillage systems (Stolf et al., 2010).

As with other implements, harrows operational review, according to Serrano (2007), can be performed based on fuel consumption per hectare measurement, which is the main technical indicator in the agricultural machinery efficiency use assessment, since it demonstrates the involvement of the several variables that affect fuel supplied to the engine transformation efficiency, during the work done by the implement.

Using a harrow in conventional tillage system, Tavares et al. (2012) described that the operating fuel consumption is 20.9% lower when compared to reduced tillage system using chisel.

Within the present context, this work aims to evaluate the operating performance of a harrow in clay soil using different engine work speeds.

Material and methods

The test was conducted in the agricultural year of 2010/2011, at the Lageado Experimental Farm, which belong to the Faculty of Agricultural Sciences - UNESP, located in the municipality of Botucatu - SP, in the central west region of São Paulo state, with the approximate geographical coordinates of Latitude 22° 51' S and longitude 48° 26' W Greenwich, average altitude of 770 meters and an average declivity of 4.5%.

The experimental area soil was classified as Dystrophic Red Nitosol, according to EMBRAPA (1999) classification. Approximately 90 days before the test, corn was harvested in the experimental area, providing to the experimental area soil 8 t ha⁻¹ of cover with crop residues and spontaneous cover vegetation, which consisted predominantly of *Brachiaria decumbens* and *Panicum maximum*. For soil granulometric characterization, were collected four samples at a depth of 0-20 cm, resulting in a composite sample that was subjected to granulometric analysis, according to SBCS (2004) procedure. The results of this analysis are shown in Table 1.

Table 1 - Experimental area granulometric analysis for the depth of 0-20 cm.

Sand (g kg ⁻¹)	Clay (g kg ⁻¹)	Silt (g kg ⁻¹)	Texture
165	450	385	Clayey

The experimental design was a randomized complete block design with 3 treatments and 4 replicates, for a total of 12 experimental plots. Used treatments were three different engine speeds, with 157 rad s⁻¹ (1500 rpm), 189 rad s⁻¹ (1800 rpm) and 220 rad s⁻¹ (2100 rpm), all in B1 gear escalation. Plots were dimensioned to be 20 m long and with 3.5 m overall width, spaced 15 m from each other, to perform the required maneuvers and stabilizing the tractor-harrow set.

In the experiment implementation and conduct, a John Deere brand tractor was used, 6600

model, with front wheel auxiliary traction (4x2 TDA), with 91.48 kW (121 hp) engine power.

To perform the tillage, a Marchesan GAICR model Intermediate Off-Set harrow with 20 disks cut in both sections, spaced at 0.27 m, 0,71 m (28 inches) in diameter, cutting width of 2.57 m and work depth of 0.12 to 0.20 m were used.

To determine harrow working depth, the surface profilometer method was used, as described by Lanças & Benez (1987). Vertical soil displacement in the mobilized area was assessed, in which the natural profile, background and soil elevation survey

was performed.

First, readings were taken at the soil surface profile, prior to the preparation. After preparation, readings were performed to determine soil swelling caused by harrows; then, a groove was manually opened with the aid of a mattock, removing any soil mobilized by the active equipment organs, in order to evaluate the subsurface soil profile, at the same location where the surface profile and the swelling reading was performed. To properly schedule and ensure that the three readings were taken at the same location, two piles embedded into the soil were used, one on each side, which also served as profilometer support base.

To determine wheels slipping, pulse generators from S & E tests and measurement Instrument brand, IGoE-60-U12V model, was used, which performed rotary motion or linear displacements conversion into electrical pulses, generating 60 pulses per tractor wheelset revolution. Wheels pulse generators were fixed in the tractor wheels center.

To determine the average bar traction force (Fbt), a Sodemex brand load cell, N-400 model was used, with a capacity of 100 kN and sensitivity of 2.16 mV V⁻¹.

Tractor fuel consumption per hour (Chc) measurement was performed using the "Flowmate" brand flowmeter, Oval M-III model, with accuracy of 0.01 L. This flowmeter generates a pulse at every milliliter (mL) of fuel consumed by tractor.

For the acquisition and tracking of the signals obtained by sensors in the fuel supply system and the load cell, a panel with indicator electronic instruments panel of "MICRO-P" type.

The effective working speed (Ve) of the tractor-harrow set, which is the actual displacement speed of the set operating in the plot, was obtained by Equation (1), with the rout time recorded with the aid of a digital stopwatch.

$$Ve = (\Delta S / \Delta T) \times 3.6 \tag{1}$$

Where Ve is the effective working speed (km h⁻¹) ΔS the plot distance (m) and ΔT the rout time (s).

Having the Fbt and Ve data, the average power required in the traction bar was calculated (Pbt) according to Equation (2), suggested by Lopes et al. (2010).

$$Pbt = Fbt \times (Ve / 3.6) \tag{2}$$

Where Pbt is the average power required in the traction bar (kW), Fbt is the average force in the bar (kN), obtained by the load cell and MICRO-P panel, and Ve is the effective working speed (km h⁻¹).

The effective field capacity (Equation 3), which is the amount of hectares per hour worked by the set, was calculated through the effective tractor speed and the implement actual width.

$$Cce = (L \times Ve) / 10 \tag{3}$$

Where Cce is the effective field capacity (ha h⁻¹), L is the working width (m) and Ve is the effective working speed (km h⁻¹).

The operational fuel consumption, which represents the fuel consumption per worked area, was obtained from the relation between hourly fuel consumption and effective field capacity, according to Equation (4).

$$COC = Chc / Cce \tag{4}$$

Where COC is the operational fuel consumption (L.ha⁻¹), Chc the hourly fuel consumption (L h⁻¹) and Cce the effective field capacity (ha h⁻¹).

The results were submitted to analysis of variance at 5% probability by F test, and the treatment means were compared by Tukey test at 5% significance level.

Results and discussions

As shown in Table 2, the results of operational fuel consumption (COC), effective field capacity (Cce), effective work speed and harrow work depth showed significant differences for the different used engine speeds.

The 220 rad s⁻¹ (2100 rpm) rotation had most effective working speed results, 3.65 km h⁻¹, higher Cce, 0,91 ha h⁻¹, and reduced COC, 17.25 L ha⁻¹. In this rotation, the COC was of 47.4 and 13.5% lower than the engine COC in 157 rad s⁻¹ (1500 rpm) and 189 rad s⁻¹ (1800 rpm) regime, respectively. This COC result at 220 rad s⁻¹ (2100 rpm) is similar to that found by Salvador et al. (2009), in 16.41 L ha⁻¹.

Table 2 - Effective work speed, effective field capacity, operational fuel consumption, average work depth, traction bar average force and front and rear slipping in function of engine rotation.

Engine rotation (rad s ⁻¹ - rpm)	¹ Ve (km h ⁻¹)	² Cce (ha h ⁻¹)	³ COC (L ha ⁻¹)	Work depth (cm)	Average force (N)	Average power (kW)	Slipping (%)	
							Front	Rear
157 - 1500	2.50 c	0.62 c	32.85 a	17.7a	15275a	10.57c	14.2a	14.4a
189 - 1800	3.05 b	0.76 b	19.95 b	17.5a	15012a	12.65b	14.4a	14.4a
220 - 2100	3.65 a	0.91 a	17.25 c	13.1b	14100a	14.23a	15.2a	14.9a
C.V. (%)	2.61	2.56	4.3	11.12	6.4	0.68	7.82	6.27

¹Effective work speed. ²Effective field capacity. ³Operational fuel consumption. Means followed by the same letter in the column do not differ by t test at 5% probability.

While assessing operating performance of tandem and light off-set harrow with 22" and 24" diameter disks, Cortez et al. (2011) found work speeds between 5.04 and 5.76 km h⁻¹ and Cce between 0.93

and 1.10 ha h⁻¹. The speeds found in this study are different from those mentioned in lower values, what can be explained due to the used harrow having 0,71 m (28 inches) diameter disks, which are heavier and reach deeper work depth. Cce lower values in this study can be justified and discussed in function of used harrow lower speeds and work width. A width of 2.57 m and maximum speed of 3.65 km h⁻¹ at 220 rad s⁻¹ (2100 rpm) are limiting factors to Cce. Harrows used by the authors had a width of 2.8 m and speed of up to 5.76 km h⁻¹.

Similar Cce results were found by Silveira et al. (2006), who found for harrow preparation the effective field capacity of 0.86 ha h⁻¹.

The harrow work depth, which is a factor directly related to operation quality, was lower for 220 rad s⁻¹ (2100 rpm) rotation. The lowest depth, 13.1 cm, can be explained due to 220 rad s⁻¹ (2100 rpm) rotation having caused higher harrow work speed (3.65 km h⁻¹). In higher work speeds, harrow disks tend to deepen less and require less traction force and bar power, resulting in lower COC. These results are equivalent to those found by Levien et al. (2003) and Cunha et al. (2011), who also worked with harrow disks.

Pequeno et al. (2012), while evaluating the performance of a tractor-harrow set in the Brazilian northeastern semi-arid working in 214 rad s⁻¹ (2040 rpm) rotation, authors found that for higher work speed there was a significant work depth reduction, of 0.11 m to 0.09 m, explained as a harrow floating effect. It was also found that the increase in speed requires more power in the traction bar, with traction force not being changed.

Assuming that the engine rotation speed and the effective work speed may be decision making questions in the harrowing operation, the choice of 220 rad s⁻¹ (2100 rpm) rotation and 3.65 km h⁻¹ enables fuel economy and higher worked area amount per unit time, which are desirable results to reduce operational costs. In contrast, the increase in effective speed reduces harrow work depth, from 2.5 km h⁻¹ (157 rad s⁻¹; 1500 rpm) to 3.65 km h⁻¹; the depth is reduced in approximately 26%, going from 17.7 to 13.1 cm. The consequence is tillage with compromised quality, being only superficially mobilized, as the profilometer result shown in Figure 1.

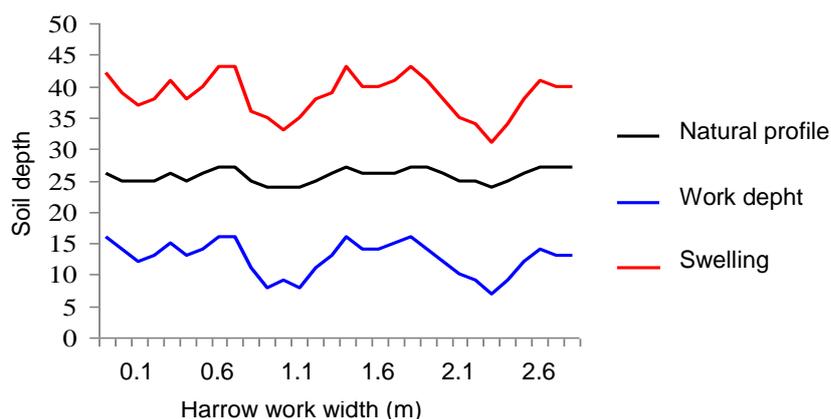


Figure 1 - Graphical representation of work depth, swelling and soil natural profile prepared with disk harrow in 220 rad s⁻¹ (2100 rpm) engine rotation and effective speed of 3.65 km h⁻¹.

Although effective speeds were significantly different for the three engine speeds, and work depth was lower at 220 rad s⁻¹ (2100 rpm), average power on the traction bar results were not significantly different between rotations. However, bar average power results differed significantly between the three rotations, being higher for 220 rad s⁻¹ (2100 rpm). Lopes et al. (2010) stated that the traction bar power is related to traction force and operation speed, the latter influenced by work depth. Thus, the larger the work depth, higher the traction force, lower the movement speed and higher is the power required in the bar. However, the results have not accurately culminated in all relations clarified by the authors, and also in Grotta et al. (2008), and the higher required power at 220 rad s⁻¹ (2100 rpm) may be related only to higher V_e , the used gear escalation (B1) and the harrow setting. Stolf et al. (2010), while studying harrows work angle, correlated dimensional characteristics

and adjustments to its required power.

Tractor front and rear wheels slippage fluctuated between 14.2 and 15.2%, and 14.4 and 14.9%, respectively, with no significant difference between them for the three engine rotation speeds. However, the front slip slightly higher at 220 rad s⁻¹ (2100 rpm) can also contribute to the result of higher required average power.

Conclusions

Disk harrow operating performance in clay soil enables lower fuel consumption and higher effective field capacity when 220 rad s⁻¹ (2100 rpm) engine rotation was used. In contrast, work depth was reduced and the power required on the bar increased.

Lower engine rotation speed provides higher work depth and less power in the traction bar.

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