ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
v.20, n.3, p.286–291, 2016
Campina Grande, PB, UAEA/UFCG – http://www.agriambi.com.br

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v20n3p286-291

Performance of a seeder according to the displacement velocity and furrowing mechanism for fertilizer deposition

Viviane C. dos Santos[1], Paulo R. A. dos Santos[1], Isabela O. Lima[1], Valberto R. F. Pereira[1], Flávio R. F. Gonçalves[1] & Carlos A. Chioderoli[1]

[1] Universidade Federal do Ceará/Centro de Ciências Agrárias/Departamento de Engenharia Agrícola. Fortaleza, CE. E-mail: vihcs@live.com (Corresponding author); paulo_ptg@hotmail.com; isabelaoliveiralima@yahoo.com.br; valbertofeitosa@uol.com.br; flaviorobertogoncalves@gmail.com; ca.chioderoli@ufc.br

Key words:
seeding
plow shank
offset double disc
longitudinal distribution
specific consumption

ABSTRACT
Agribusiness daily increases the demand for machinery with better efficiency, seeking to reduce operating costs and improve the quality of the sowing process. The objective of present study was to evaluate the quality of the longitudinal seed distribution and the operating performance of a seeder-fertilizer according to displacement velocity and furrowing mechanism for fertilizer deposition. The assay was conducted in the experimental area of the Department of Agricultural Engineering of the Federal University of Ceará. The experimental design was randomized blocks, in a 2 x 3 factorial, with four replicates with two furrowing mechanisms for fertilizer deposition (double disc and shank) and three displacement velocities (4.7, 6.3 and 8.2 km h^{-1}). The results demonstrate that for the quality of seed distribution, the best performance was obtained with the use of the shank at velocity of 6.3 km h^{-1}. The tractor-seeder set provided better operating performance using the disc, which promoted the lowest specific consumption at the velocity of 4.7 km h^{-1}.

Palavras-chave:
semeadura
haste sulcadora
disco duplo desencontrado
distribuição longitudinal
consumo específico

Desempenho de semeadora-adubadora em função da velocidade de deslocamento e do mecanismo sulcador de fertilizantes

RESUMO
Diariamente, o agronegócio aumenta a exigência por maquinário com melhor eficiência buscando a redução dos custos operacionais e a melhoria da qualidade do processo de semeadura. O objetivo do trabalho foi avaliar a qualidade da distribuição longitudinal de sementes e o desempenho operacional de uma semeadora-adubadora em função da velocidade de deslocamento e do mecanismo sulcador de fertilizantes. O trabalho foi realizado na área experimental do Departamento de Engenharia Agrícola da Universidade Federal do Ceará. O delineamento experimental foi em blocos casualizados, em esquema fatorial 2 x 3 com 4 repetições e dois mecanismos para depósito de fertilizantes (disco duplo desencontrado e haste sulcadora) além de três velocidades de deslocamento (4,7; 6,3 e 8,2 km h^{-1}). Os resultados demonstram que para qualidade da distribuição de sementes o melhor desempenho foi com o uso da haste sulcadora na velocidade de 6,3 km h^{-1}. O conjunto trator-semeadora obteve melhor desempenho operacional com o uso do disco obtendo menor consumo específico na velocidade de 4,7 km h^{-1}.

Received 433-2014 – 5 Dec, 2014 • Approved 11 Sep, 2015 • Published 30 Jan, 2016

Introduction

Agricultural equipment, when properly used, have better operational performance and facilitate the tasks of the farmer in the field, allowing higher yields in planting areas, productivity and optimization of the schedule of activities (Modolo et al., 2005).

According to Seki et al. (2012), when the sowing operation is performed, the adequate stand and distribution uniformity of seeds are factors with great influence on the agricultural production. These components can be affected by many variables and the operating velocity of the seeder-fertilizer is one of the most important.

The displacement velocity of the tractor-seeder set is a relevant factor in the sowing operation, since it influences aspects such as: fuel consumption (Palma et al., 2010), sowing quality (Melo et al., 2013) and operational capacity (Silveira et al., 2012).

According to Cepik et al. (2005), as the tractor displacement velocity increases, the traction power increases, in a dystrophic Red Argisol.

Furlani et al. (2008) highlighted that the required power for a seeder depends on factors such as: type of soil, operational velocity and depth of sowing and fertilization. These authors also report that the slippage of the seeder directly influences seed distribution; thus, it must be as low as possible.

The corn crop (*Zea mays* L.) has good root development in soils without restrictions; however, when subjected to soils with high density, root growth becomes considerably lower and even morphological alterations may be observed, such as deviation in vertical growth, concentration in more superficial soil layers and thickening of roots (Silveira, et al., 2012). Thus, agricultural practices are necessary to break these compacted surface layers. Because of the need for breaking compacted soil layers, many devices have been projected and commercialized with this purpose (Reinert et al., 2008).

With the use of plow shanks in seeder-fertilizers, they started not only to open the furrow, but also to deposit the seeds in the soil, perform a local soil tillage only along the sowing row and unpack the superficial soil layer (Furlani et al., 2013).

According to Grotta et al. (2009), depending on the type of shank and on its angle of attack, there may be greater or smaller soil mobilization, i.e., causing changes in the mobilized volume of soil, leading to possible erosive processes and requiring higher or lower power to penetrate into the soil.

This study aimed to evaluate the longitudinal distribution of corn seeds and the operational performance of a seeder-fertilizer as a function of three displacement velocities and two types of furrowing mechanism for fertilizer deposition.

Material and Methods

The study was carried out in an experimental area with Aw' climate, defined as rainy tropical, according to Köppen (1918). The soil in the area is a Red Yellow Argisol with sandy loam texture and approximately 82.90% of sand, 10.60% of clay and 6.40% of silt.

The experiment was conducted in an area previously plowed and harrowed, with history of intensive use of machines and compacted layer from 0 to 10 cm. The experimental design was randomized blocks, in 2 x 3 factorial scheme, with four replicates. The treatments consisted of two furrowing mechanisms for fertilizer deposition (offset double disc and plow shank) and three actual displacement velocities (4.7, 6.3 and 8.2 km h^{-1}) with engine rotation of 2000 rpm. Each experimental unit was 4.0 m wide and 20 m long, totaling 24 experimental units.

For the operational performance, the following parameters were evaluated: operational field capacity, mobilized area, specific resistance, traction force, drawbar power and specific, hourly and operational consumptions. For longitudinal seed distribution, the slippage and the distribution of normal, double or failed seeds were evaluated.

Two tractors were used, one Valtra®, model BM120, 4x2 front wheel assist (FWA) of 88.26 kW (120 hp) in the engine at rotation of 2000 rpm, with activated front traction, equipped with diagonal tires. The front axle had 14.9-24 R1 tires with inflation pressure of 18 psi (124 kPa) and the rear axle had 18.4-34 R1 tires with inflation pressure of 22 psi (152 kPa). The tractor was adjusted to the weight/power ratio of 55 kg hp^{-1}, with distribution of 65% on the rear axle and 35% on the front axle, using solid and liquid ballast.

The support tractor was a Massey Ferguson®, model 265, 4x2 with 47.80 kW (65 hp) attached to a precision seeder and used to form a convoy system, according to the methodology of Mialhe (1996).

The pneumatic precision seeder-fertilizer was a Jumil, model JM2090 PD, with approximate weight of 1,160 kg, mounted, with three lines spaced at 0.80 m and maximum capacity of 39 L in the deposits of fertilizer and seeds.

Fertilizer deposition was performed using a plow shank (with tip attack angle of 15º) or an offset double disc, with diameter of 14 in. Both mechanisms deposited the fertilizer at a depth of 10 cm. Seed deposition was performed using an offset double disc and a pneumatic seed meter.

Fertilizer and seed distribution systems were activated using a concave rear sprocket, made of rubber, with central relief to compact the seeds. Hybrid corn seeds were used at a population of 62,500 plants ha^{-1}, density of 0.568 kg L^{-1} and interrow spacing of 0.80 m.

The fertilizer with commercial formulation (08-28-16) had density of 1.114 kg L^{-1}, and the seeder was pulled with 75% of load capacity in the deposit of fertilizer and seeds.

The slippage of seeder tires was determined based on the diameter of the wheel and the pathway along the plot, i.e., the number of theoretical laps in relation to the number of actual laps (Silveira et al., 2012).

The evaluation of longitudinal seed distribution, according to Kurachi et al. (1989), considered double ($X_i < 0.5\ X_{ref}$), normal ($X_{ref} < X_i < 1.5\ X_{ref}$) and failed ($X_i > 1.5\ X_{ref}$) spacings.

The traction power was determined through the indirect method, according to Mialhe (1996), using a convoy of tractors, the first one, referred to as traction tractor, pulled the second one, the support tractor. The values of drawbar force (Eq. 1) were obtained using a load cell (HBM, model U 10M), with sensitivity of 135 kW, placed on the drawbar of the first tractor.

$$F_m = \frac{\sum_{i=1}^{n} F_i}{n} \times 0.0098 \quad (1)$$

where:

F_m - mean traction force (kN);
F_i - instantaneous traction force (kgf);
n - number of data recorded; and
0.0098 - conversion factor to kN.

The velocity was obtained based on the distance traveled in each experimental unit over the time necessary to complete the course, measured using a timer. The mean power demand on the drawbar was calculated based on the mean force on the drawbar and on the actual displacement velocity.

Fuel hourly consumption (Eq. 2) was measured with flow meters (OVAL Flowmate, Model LSF 41), with precision of 0.01 mL, installed in series. Fuel consumption was determined in all the experimental plots in volume unit (mL) and by the difference between the volumes of fuel determined at the entrance and in the return of the injection pump and injection nozzles, thus obtaining the actual volume used by the tractor during the course.

$$C_h = \frac{q}{t} \times 3.6 \quad (2)$$

where:

C_h - hourly fuel consumption, L h^{-1};
q - volume consumed in the plot, mL; and
t - time to move along the plot, s.

For the calculation of fuel consumption per power unit in the drawbar, the specific consumption and the power in the drawbar were calculated using Eq. 3.

$$C_e = \frac{C_h}{P_b} \times d \quad (3)$$

where:

C_e - specific fuel consumption, kg kW h^{-1};
C_h - hourly fuel consumption, L h^{-1};
P_b - mean power in the drawbar, kW; and
d - fuel density, kg L^{-1}.

The mobilized area was determined using a steel profilometer, with 50 vertical rods with 0.64 m of length, spaced at 0.01 m and arranged across the sowing row. Two profiles were determined in all the rows: the profile of the natural soil surface and the bottom profile of the mobilized soil.

The profile was marked using millimeter paper and the curves were drawn by the profilometer. After the construction of the curves, delimiting the natural and bottom soil profiles, according to the theory of differential and integral calculus (Thomas et al., 2012), upper and lower sums were obtained for the estimation of the area.

The mobilized soil area consists in the area situated between the natural soil profile and the bottom profile of the furrow.

The lower sums were used with the construction of vertical rectangles with 0.005 m of width and height, which cannot surpass the drawn lines. Then, the formula of the rectangle area was used to determine each partial area; the mobilized area (Eq. 4) corresponds to the sum of these partial areas, i.e.:

$$MSA = \sum_{i=1}^{n} 0.5h_n \quad (4)$$

where:

h_n - rectangle height of order n.

The specific operational resistance was obtained using Eq. 5, taking into consideration the mean traction force and the area mobilized by the active component of the seeder.

$$SOR = \frac{F_m}{MSA} \quad (5)$$

where:

SOR - specific operational resistance, kN m^{-2};
F_m - mean traction force, kN; and
MSA - mobilized soil area, m^2.

The operational field capacity was obtained based on the working width of the seeder-fertilizer and the actual displacement velocity, considering an efficiency of 75% of the effective field capacity, according to ASAE (1997).

The coefficient of skewness and kurtosis was used to verify data normality, for which values higher than 2 and lower than -2 represent great deviation from normal distribution. All the observed values did not exceed the limits between 2 and -2; therefore, the hypothesis of normality must be considered (Montgomery, 2004).

The results were subjected to analysis of variance by F test ($p < 0.05$) and, when significant, the means were compared by Tukey test at 0.05 probability level.

Results and Discussions

The mean values of operational field capacity, mobilized area, specific resistance and traction force of the tractor-seeder set are shown in Table 1.

For both mechanisms used, the operational field capacity did not show significant differences, due to the constant efficiency and effective width of the seeder, according to Furlani et al. (2013).

The mobilized area did not show significant difference for the mechanisms and the velocities. These results can be justified by the fact that the soil was sandy and possibly above the friability state, which allows its lateral mobilization. This differs from the results found by Mion & Benez (2008), who observed that the plow shank promoted greater mobilized area in comparison to the double disc.

The specific operational resistance showed differences for the mechanisms and the plow shank obtained higher specific resistance; these values can be justified by the higher traction force demanded by the shank. Francetto et al. (2015)

Table 1. Mean values of operational field capacity (OFC), mobilized soil area (MSA), specific resistance (SR) and traction force (TF) in corn sowing with two furrowing mechanisms and three velocities

Source of variation		OFC (ha h^{-1})	MSA (m^2)	SR (kN m^{-2})	TF (kN)
Mechanism (M)	Shank	1.14	0.06	163.13 a	10.13 a
	Disc	1.16	0.07	112.45 b	7.43 b
Velocity (V)	4.7	0.84 c	0.07	126.81	8.42 b
	6.3	1.14 b	0.06	135.50	8.76 ab
	8.2	1.47 a	0.06	151.05	9.15 a
F value	M	2.42^{NS}	0.163^{NS}	8.54 *	174.58 *
	V	745.86 *	0.62^{NS}	0.67^{NS}	4.20 *
	M*V	0.24^{NS}	0.132^{NS}	0.80^{NS}	8.57 *
LSD	M	0.03	0.02	36.94	0.43
	V	0.04	0.02	55.17	0.17
CV (%)		2.84	29.27	30.81	5.70

* Significant at $p < 0.05$; ^{NS} - Not significant; Means followed by the same letter and without letters in the columns do not differ by Tukey test ($p > 0.05$); LSD - Least significant difference

obtained different results, in which the double disc showed higher specific resistance, compared with the plow shank, and obtained significant increment with the increase in velocity. In the present study, there was no significant difference with the increase in velocity.

The traction force differed between the mechanisms and the velocities. As indicated by Rosa et al. (2008), the disc consumes less energy than the shank does for its displacement, without promoting increment or decrease in the mobilized area. This phenomenon is probably due to the form of action of the mechanisms. According to Silva (2003), the shank moves by sliding in the soil and promotes greater disturbance in the sowing row, undoubtedly receiving greater resistance, which leads to higher traction force.

The traction force values differed statistically and there was interaction between the variables (Table 2).

The plow shank, at all the velocities, showed higher values of traction force compared with the double disc, because, although the plow shank and the double disc deposit fertilizer at the same depth, the mechanisms have different working depths and, probably, the plow shank demands more force because it has larger area of action. Mercante et al. (2005) obtained similar results and observed that the force required by the shank was approximately 19% higher than that required by the double disc.

For the shank, when the velocity increased, there was an increment in the demand of force in the drawbar and no difference was observed between the velocities of 6.3 and 8.2 km h^{-1}. Similar results were found by Furlani et al. (2013), evaluating different types of shanks in no-till systems.

For the offset double disc, the demand of force did not increase with the increment in velocities and there were no significant differences between them, i.e., with the use of double disc, it is possible to work at higher velocities without increasing the demand for traction force. Silva & Benez (2005) report that this increase in traction force occurs in the shank and not in the disc, because the shank is projected to open the furrow to deposit the fertilizer, as the double disc, but it also has the function of breaking compacted soil layers. Possibly, with the increase in velocity, the demand of power to break the layers becomes higher.

Table 2. Mean values of traction force in corn sowing with two furrowing mechanisms and three velocities

Source of variation		Velocity (V) – km h^{-1}		
		4.7	6.3	8.2
Mechanism (M)	Shank	9.20 Ba	10.25 Aa	10.93 Aa
	Disc	7.65 Ab	7.26 Ab	7.37 Ab

Means followed by different letters, lowercase in the columns and uppercase in the rows, differ by Tukey test at 0.05 probability level

According to Table 3, the hourly and operational fuel consumptions did not show significant differences for both mechanisms; however, as the displacement velocity increased, there was an increment in hourly fuel consumption.

The increase in hourly fuel consumption is explained by the higher demand of the tractor with the increase in velocity. In the case of operational fuel consumption, it means that even with the increase in tractor demand at the highest velocity, this is compensated by the greater operational capacity of the set. According to Silveira et al. (2013), the demand of power per sowing row is approximately 4.72 kW; with the sowing in three rows, it becomes about 19.2 hp. Considering the losses until the engine, 47.4 hp would be necessary to pull the seeder and the tractor used has 120 hp, i.e., this tractor is oversized for this operation. Therefore, even with the increase in force, the operational consumption does not change and these results corroborate those found by Furlani et al. (2007).

For the evaluated mechanisms, only the specific consumption showed significant difference and the shank promoted higher specific consumption, which can be explained by the greater demand of power in the tractor.

The values of mean power in the drawbar differred statistically and there was interaction between the variables (Table 4).

The seeder equipped with a shank showed higher demand of power in comparison to that equipped with a disc. At all evaluated velocities, the greater the velocity, the higher the demand of power in the drawbar, for both mechanisms used. According to Bellé et al. (2014), as the velocity increases, the demand of power also increases.

The operation velocity significantly influenced failed and normal spacings (Table 5), while the velocity of 8.2 km h^{-1}

Table 3. Mean values of specific consumption (SC), hourly consumption (HC) and operational consumption (OC) in corn sowing with two furrowing mechanisms and three velocities

Source of variation		SC (kg kW h^{-1})	PD (kW)	HC (L h^{-1})	OC (L ha^{-1})
Mechanism (M)	Shank	0.51 b	18.18 a	10.54	9.25
	Disc	0.74 a	13.31 b	11.41	9.97
Velocity (V)	4.7	0.69	10.99 c	8.70 b	10.29
	6.3	0.63	15.39 b	11.03 ab	9.59
	8.2	0.56	20.34 a	13.21 a	8.95
F value	M	9.70*	113.94*	0.56^{NS}	0.55^{NS}
	V	0.94^{NS}	155.95*	5.07*	0.62^{NS}
	M*V	0.43^{NS}	14.07*	0.72^{NS}	0.58^{NS}
LSD	M	0.16	0.15	2.45	2.09
	V	0.24	0.22	3.66	3.11
CV (%)		29.35	2.72	25.72	24.97

* Significant at $p < 0.05$; ^{NS}Not significant; Means followed by the same letters and without letters in the columns do not differ by Tukey test ($p > 0.05$); PD - Power in the drawbar; LSD - Least significant difference

Table 4. Mean values of power in the drawbar in corn sowing under two furrowing mechanisms (M) and three velocities (V)

Source of variation		Velocity (V) – km h^{-1}		
		4.7	6.3	8,2
Mechanism (M)	Shank	11.95 Ca	17.82 Ba	24.76 Aa
	Disc	10.04 Cb	12.96 Bb	16.92 Ab
LSD	M		1.68	
	V		2.05	

*Means followed by different letters, lowercase in the columns and uppercase in the rows, differ by Tukey test at 0.05 probability level; LSD - Least significant difference

Table 5. Mean values of seeder slippage and distribution of normal and failed seeds in corn sowing under two furrowing mechanisms and three velocities

Source of variation		Seeder slippage	Normal seeds	Failed seeds
			(%)	
Mechanism (M)	Shank	-16.82 a	84.10 a	15.90 b
	Disc	-13.00 b	79.56 b	20.43 a
Velocity (V - km h^{-1})	4.7	-13.61	84.82 a	15.17 b
	6.3	-15.34	84.95 a	17.05 b
	8.2	-15.79	77.73 b	22.27 a
F value	M	14.26*	22.35*	22.35*
	V	1.73 ^{NS}	19.63*	19.63*
	M*V	2.01 ^{NS}	0.54 ^{NS}	0.54 ^{NS}
LSD	M	2.15	2.04	2.04
	V	3.22	3.05	3.05
CV (%)		16.62	2.87	12.93

* Significant at $p < 0.05$; ^{NS}Not significant; Means followed by the same letter and without letters in the columns do not differ y Tukey test ($p > 0.05$); LSD - Least significant difference

showed significant increase in failed spacings and reduction of normal spacings, in comparison to the velocities of 4.7 and 6.3 km h^{-1}, which did not differ. However, the obtained results differ from those of Mercante et al. (2005), who observed that seed distribution uniformity was not significantly affected by the change in velocity. On the other hand, Dias et al. (2009) and Liu et al. (2010) found similar results, in which the velocity influenced seed distribution.

The slippage of seeder tires was higher with the use of the shank, which differred significantly from the double disc. It is inferred that the pressure of the tire on the soil and also the formation of microrelief reduced the contact of the drive wheel with the soil, increasing the slippage. As to the velocities, there was no significant difference, i.e., even with the increase in velocity, there is no increment in the seeder slippage and these results differ from those found by Palma et al. (2010), who observed increase in slippage with the increment in velocity.

Even with the significant differences in the seed distribution uniformity, as the sowing velocity increased, all the velocities showed acceptable spacings in the range of 75 to 90%, besides good sowing performance (Trogello et al., 2013).

Conclusions

1. The best longitudinal seed distribution was obtained with the use of the shank at the velocities of 4.7 and 6.3 km h^{-1}.

2. The tractor-seeder set obtained better operational performance with the use of the disc, which promoted the lowest specific consumption at the velocity of 4.7 km h^{-1}.

Literature Cited

ASAE - American Society of Agricultural Engineers. Terminology and definitions for agricultural tillage implements. SAE S414.1. In: ASAE standards 1997: Standards engineering practices data. St. Joseph: 1997. p.254-275.

Bellé, M. P.; Alonço, A. dos S.; Francetto, T. R.; Rossato, F. P.; Frank, C. J.; Carpes, D. P. Demanda energética e mobilização do solo com uso de escarificadores em sistema de semeadura direta. Revista Brasileira de Engenharia Agrícola e Ambiental, v.18, p.551-558, 2014. http://dx.doi.org/10.1590/S1415-43662014000500013

Cepik, C. T. C.; Trein, C. R.; Levien, R. Força de tração e volume de solo mobilizado por haste sulcadora em semeadura direta sobre campo nativo, em função do teor de água no solo, profundidade e velocidade de operação. Engenharia Agrícola, v.25, p.447-457, 2005. http://dx.doi.org/10.1590/S0100-69162005000200018

Dias, V. O.; Alonço, A. S.; Baumhardt, U. B.; Bonotto, G. J. Distribuição de sementes de milho e soja em função da velocidade e densidade de semeadura. Ciência Rural, v.39, p.1721-1728, 2009. http://dx.doi.org/10.1590/S0103-84782009005000105

Francetto, T. R.; Alonço, A. S.; Bellé, M. P.; Franck, C. J.; Dauto P. Carpes, D. P. Comportamento operacional de associações entre sulcadores e discos de corte para sistema de semeadura direta. Engenharia Agrícola, v.35, p 542-554, 2015.

Furlani, C. E. A.; Canova, R.; Cavichioli, F. A.; Bertonha, R. S.; Silva, R. P. Demanda energética por semeadora-adubadora em função da haste sulcadora na semeadura do milho. Revista Ceres, v.60, p.885-889, 2013. http://dx.doi.org/10.1590/S0034-737X2013000600017

Furlani, C. E. A.; Cortez, J. W.; Silva, R. P.; Grotta, D. C. C. Cultura do milho em diferentes manejos de plantas de cobertura do solo em plantio direto. Revista de Biologia e Ciências da Terra, v.7, p.161-167, 2007.

Furlani, C. E. A.; Silva, R. P. da; Filho, A. C.; Cortez, J. W.; Grotta, D. C. C. Semeadora-adubadora: Exigências em função do preparo do solo, da pressão de inflação do pneu e da velocidade. Revista Brasileira de Ciência do Solo, v.32, p.345-352, 2008. http://dx.doi.org/10.1590/S0100-06832008000100032

Grotta, D. C. C.; Furlani, C. E. A.; Silva, R. P.; Lopes, A.; Reis, G. N. Semeadora-adubadora: Demanda energética em função do manejo da cobertura vegetal e da profundidade da haste de deposição de adubo em sistema plantio direto. Engenharia Agrícola, v.29, p.241-248. 2009. http://dx.doi.org/10.1590/S0100-69162009000200007

Köppen, W. Klassifikation der klimate nach temperatur, niederschlag und jahresablauf. Petermanns Geographische Mitteilungen, v.64, p.193-203, 1918.

Kurachi, S. A. H.; Costa, J. A. S.; Bernardi, J. A.; Coelho, J. L. D.; Silveira, G. M. Avaliação tecnológica de semeadoras e/ou adubadoras: tratamento de dados de ensaios e regularidade de distribuição longitudinal de sementes. Bragantia, v.48, p.249-262, 1989. http://dx.doi.org/10.1590/S0006-87051989000200011

Liu, J.; Chen, Y.; Kushwaha, R. L. Effect of tillage speed and straw length on soil and straw movement by a sweep. Soil and Tillage Research, v.109, p.9-17, 2010. http://dx.doi.org/10.1016/j.still.2010.03.014

Melo, R. P.; Albiero, D.; Souza, F. H.; Silva, J. G. Qualidade na distribuição de sementes de milho em semeadoras em um solo cearense. Revista Ciência Agronômica, v.44, p.94-101, 2013. http://dx.doi.org/10.1590/S1806-66902013000100012

Mercante, E.; Silva, S. de L.; Modolo, A. J.; Silveira, J. C. M. da. Demanda energética e distribuição de sementes de milho em função da velocidade de duas semeadoras. Revista Brasileira de Engenharia Agrícola e Ambiental, v.9, p.424-428, 2005. http://dx.doi.org/10.1590/S1415-43662005000300020

Mialhe, L. G. Máquinas agrícolas: Ensaios & certificação. 1.ed. Piracicaba: Fundação de Estudos Agrários Luiz de Queiroz, 1996. 722p.

Mion, R. L.; Benez, S. H. Esforços em ferramentas rompedoras de solo de semeadoras de plantio direto. Ciência e Agrotecnologia, v.32, p.1594-1600, 2008. http://dx.doi.org/10.1590/S1413-70542008000500036

Modolo, A. J.; Silva S. L.; Filho, A. G.; Silveira, J. C. M.; Gnoatto, E. Demanda energética solicitada por uma semeadora-adubadora de precisão com diferentes unidades de semeadura. Revista Acta Scientiarum, v.27, p.473-479, 2005. http://dx.doi.org/10.4025/actasciagron.v27i3.1459

Montgomery, D. C. Introdução ao controle estatístico da qualidade. 4. ed. Rio de Janeiro: LTC, 2004. 563p.

Palma, M. A. Z.; Volpato, C. E. S.; Barbosa, J. A.; Spagnolo, R. T.; Barros, M. M.; Boas, L. A. V. Efeito da profundidade de trabalho das hastes sulcadoras de uma semeadora-adubadora na patinagem, na força de tração e no consumo de combustível de um trator agrícola. Ciência e Agrotecnologia, v.34, p.1320-1326, 2010. http://dx.doi.org/10.1590/S1413-70542010000500034

Rosa, D. P. da; Reichert, J. M.; Sattler, A.; Reinert, D. J.; Mentges, M. I.; Vieira, D. A. Relação entre solo e haste sulcadora de semeadora em Latossolo escarificado em diferentes épocas. Pesquisa Agropecuária Brasileira, v.43, p.395-400, 2008. http://dx.doi.org/10.1590/S0100-204X2008000300015

Reinert, D. J.; Reichert, J. M.; Aita, C.; Albuquerque, J. A.; Andrada, C. Limites críticos de densidade do solo para o crescimento de raízes de cobertura em argissolo vermelho. Revista Brasileira de Ciência do Solo, v.32, p.1805-1816, 2008. http://dx.doi.org/10.1590/S0100-06832008000500002

Seki, A. S.; Benez, S. H.; Silva, P. R. A. Desempenho operacional da semeadora e produtividade do milho em plantio direto e cultivo mínimo. Revista Energia na Agricultura, v.27, p.1-18, 2012. http://dx.doi.org/10.17224/EnergAgric.2012v27n1p01-18

Silva, P. R. A. Mecanismo sulcadores de semeadora-adubadora na cultura do milho (*Zea mays* L.) no sistema de plantio direto. Botucatu: UNESP. 2003. 84p. Dissertação Mestrado

Silva, P. R. A.; Benez, S. H. Avaliação de forças resultantes de mecanismos sulcadores de semeadoras-adubadoras de plantio direto. Engenharia Agrícola, v.20, p.76-82, 2005.

Silveira, J. C. M.; Fernandes, H. C.; Leite, D. M.; Teixeira, M. M.; Furtado Júnior, M. R. F. Avaliação da qualidade da semeadura direta do milho em função do aumento da velocidade de deslocamento e do escalonamento de marcha de um conjunto Trator-Semeadora-Adubadora. Engenharia na Agricultura, v.20, p.95-103, 2012. http://dx.doi.org/10.13083/1414-3984.v20n02a01

Silveira, J. C. M.; Fernandes, H. C.; Modolo, A. J.; Silva, S. L.; Trogello, E. Demanda energética de uma semeadora-adubadora em diferentes velocidades de deslocamento e rotações do motor. Revista Ciência Agronômica, v.44, p.44-52, 2013. http://dx.doi.org/10.1590/S1806-66902013000100006

Thomas, G. B.; Weir, M. D.; Hass, J. Cálculo I. 12.ed. São Paulo: Pearson, 2012. 800p.

Trogello, E.; Monolo, A. J.; Scarsi, M.; Dallacort, R. Manejos de cobertura, mecanismos sulcadores e velocidades de operação sobre a semeadura direta da cultura do milho. Bragantia, v.72, p.101-109, 2013. http://dx.doi.org/10.1590/S0006-87052013005000016