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Operational and Energetic Performance of an Agricultural Tractor During Direct and Conventional Sowing

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Abstract
The aim of this work was to evaluate the operational performance of a tractor and precision planter-fertilizer set during corn sowing, under three displacement speeds: 3.0, 5.0 and 8.0 km h^{-1} (0.83, 1.40 and 22.2 m s^{-1}) and two kinds of sowing – direct and conventional. The design used was on randomized blocks, in a 3x2 factorial arrangement, with three repetitions for each treatment. Data was gathered on tractor average traction power; average power on tractor drawbar; performance on drawbar; effective field capacity; field efficiency; hourly fuel consumption; specific fuel consumption; operational fuel consumption; energetic fuel consumption per area; slip of wheelsets and longitudinal distribution of seeds. It was observed that displacement speed influenced the variables: power on tractor drawbar; performance on drawbar; hourly fuel consumption; specific fuel consumption; operational fuel consumption; effective field capacity; field efficiency; slip of wheelsets and longitudinal distribution of seeds.

Keywords: Fuel consumption, slip, planter-fertilizer.

Introduction

Tillage operations are among the techniques that very often improve cultures production, if adapted for specific conditions of a given production system. According to Vale et al. (2008), when tillage operations to production of cultures are composed mainly by plowing and harrowing, those are characterized by excessive soil disturbance resulting on removal of the surface coverage of soil. For that reason, they are questioned by the growing and severe erosion problems, loss of soil fertility and humidity and its progressive compression.

However, in conservationist systems, as direct planting, the aim is to keep the soil coverage in order to reduce the problems due to excessive motion and soil exposition by seeding straight over plant remains. On conservationist systems, the soil and coverage conditions are usually less propitious to seed and fertilizer deposition, than the ones found on preparations with intense mobilization, being needed more care on this operation (Cortez, 2007).

On direct seeding systems, it is important that the planter-fertilizer has good resistance, but also, high capacity and operational efficiency with lower energy consumption. This way, performance evaluations of planters on different conditions of coverage and operation are conducted by researchers aiming to establish the best working parameters.

Canova et al. (2007) evaluated the distribution of soya seed with three displacement speeds (6.0 km h^{-1}; 8.0 km h^{-1} e 9.0 km h^{-1}) and different changes on the planter-fertilizer seed metering mechanism. It was observed that according to increases in displacement speed a reduction on seed distribution happened. The number of seed by meter ranged between 15.4 and 18.8 seeds.

Garcia et al. (2006) found growth on the percentage of both failed and multiple spacing and fall on acceptable spacing by increasing the displacement speed of the planter-fertilizer.

Mahl (2002) found, in average, 12% of increase on hourly fuel consumption for each km h^{-1} of increase on displacement speed, during the seeding operation. Similar result was found by Furlani et al. (1999) who, studying the planter-fertilizer operational behavior in different coverage and speed managements, found an increase on hourly fuel consumption of 6.8%, under displacement speed ranging from 4.0 to 5.0 km h^{-1}, and 11.5% from 5.0 to 6.0 km h^{-1}. Mahl (2002) and Trintin et al. (2005) also observed effects from the displacement speed on increase of hourly fuel consumption.

Specific objectives consisted to evaluate parameters of seed distribution regularity on line and evaluate the tractor performance during the seeding operation, using an automatic data acquisition system, determining the hourly fuel consumption, operational and specific, energetic consumption by worked area, average traction strength, average power on tractor drawbar, effective field capacity, field efficiency and slip of wheelsets.

Methods

The experiment was performed on a unity destined to field experiments of Universidade Estadual do Norte Fluminense, in the city of Campos dos Goytacazes, municipality of Rio de Janeiro. The work was performed on soil characterized as eutrophic Yellow Latosol, characteristic on the region. The evaluation was made on conventional seeding (CS) and direct seeding (DS) systems with corn culture.

To evaluate the machine on the conventional seeding systems, the area was previously prepared with plowing, made with an offset harrow with 14 disks of 26”. On the direct seeding system, the evaluation was made over vegetal remains and mulching of sun. The vegetal coverage management to achieve mulching formation was performed with mower, according to recommendations for the system and direct seeding.

The mechanical set for seeding was composed by a John Deere tractor, model 5705, 4X2 TDA with 85 CV of power and a planter-fertilizer for direct seeding model

Seed-Max PCR 2226, with three seeds distribution units spaced at 0.90 m.

For georeferencing of the mechanic set was used a GPS model Garmin 60Csx. The computational program GPS TrackMaker was used as interface to transfer for the computer the data acquired by the GPS. Data acquired were tabulated using Microsoft Excel, associating them to their geographic coordinates obtained by the GPS.

The evaluated parameters on the planter essay were the hourly fuel consumption, operational and specific, energetic consumption by worked area, traction strength, power on the drawbar, performance on drawbar, theoretical and effective field capacity, field efficiency and slip of tractor wheelsets.

Slip of tractor wheelsets was determined by the relation between advance and number of wheels revolutions with and without load. The advance condition with load was calculated using the distance covered during the seeding operation and the number of revolutions of the tractor wheelsets. The advance condition without load was calculated by the relation between the distance covered by the tractor-planter set in tarmac, without sliding and the number of revolutions. The space covered on the essay was defined by four revolutions of the tractor wheelsets.

During field evaluations of the tractor and planter-fertilizer set, some variables were determined straight by the flow sensors and load cell, such as the instantaneous fuel consumption. Other variables were calculated indirectly.

The slip of tractor wheelsets was calculated by Eq. 1. Each slip data was obtained dislocating the tractor in order for its wheels to complete turns.

$$S = \left(\frac{A_1 - A_n}{A_1} \right) \times 100 \qquad \text{Eq. 1}$$

where:
S - slip, %;
A_1 – advance without load by number of revolutions, m.; and
A_n – advance with load by number of revolutions, m.

From the traction values obtained by the load cell, the average traction power was calculated according to Eq. 2.

$$Pa = \frac{\sum_{i=1}^{n} Pi}{n} \qquad \text{Eq. 2}$$

where:
Pa = average traction power, N;
Pi = instantaneous traction power, N; and
n = number of data recorded.

The calculation of power demanded on drawbar was made as a function of the average traction power and displacement speed, according to Eq. 3.

$$Pdba = \frac{Pa.rs}{3.6}$$

where:
Pdba – average power on drawbar, kW; and
rs – real displacement speed of set, km h^{-1}.

Calculation of performance on drawbar was made according to Eq. 4.

$$Pdb = \frac{Pdba}{Ep} \times 100$$

where:
Pdb – Performance on drawbar, %; and
Ep – Engine power, 58.57 kW (according to manufacturer information).

The theoretical field capacity was determined by the theoretical work width of the planter and its theoretical displacement speed according to Eq. 5.

$$Tf = \frac{W.St}{10}$$

where:
Tf – theoretical field capacity, ha h^{-1};
W – useful working width of planter, m;
St – theoretical displacement speed of set, km h^{-1}; and
10 – conversion factor.

The effective field capacity was determined by the relation between worked area and total field time according to Eq. 6.

$$Ec = \frac{area}{t} \quad \text{Eq. 6}$$

where:
Ec – effective field capacity, ha h^{-1};
t – total field time, h; and
area – total worked area, ha.

Field efficiency was determined by the relation between effective and theoretical field capacities according to Eq. 7.

$$Fe = \frac{Ec}{Tf} \times 100 \quad \text{Eq. 7}$$

where:
Fe – field efficiency, %

To determinate the fuel flow, was installed a volumetric sensor FLOWMATE Oval M-III model LSF45L0- M2, with pulsing output signal and precision of 10 mL $pulse^{-1}$. The fuel flow meter was installed between the first and second fuel filters, before the injection pump. Return of the nozzles had its flow modified installing a "t" type connector before the meter. The volumetric flow sensor was installed according to Vale et al. (2008), who evaluated the performance of a tractor and mower in mowing operation.
Using the data collector model Campbell Scientific CR1000, data from fuel consumption were stored and, right after the experiment, the Datalogger computer program was used to transfer the data taken.

The hourly fuel consumption was determined according to Eq. 8.

$$Hc = \frac{v}{t} \times 3.6 \quad \text{Eq. 8}$$

where:
Hc – hourly fuel consumption, L h^{-1};
v - volume of fuel consumed, mL;
t – displacement time on parcel, s; and
3.6 – conversion factor.

The specific consumption of fuel was determined according to Eq. 9.

$$Csp = \frac{Hc.d}{Pbt} \times 1000$$

where:
Csp – specific consumption, g kW^{-1} h^{-1};
d – fuel density, 0.825 g L^{-1}; and
1000 – conversion factor.

Operational consumption was determined according to Eq. 10.

$$Oc = \frac{Hc}{Ec}$$

where:
Oc – operational consumption, L ha^{-1}.

Calculation of energy consumption per unit of worked area was made according to Eq. 11.

$$Ect = \frac{Pdb}{Ec}$$

where:
Ect – energy consumption by worked area, kWh ha^{-1}.

The average displacement speed was obtained using the GPS.

The longitudinal distribution of seeds was obtained measuring the spacing between seeds in one meter on each experimental unity on the three sowing lines. Spacing was classified in multiples, acceptable and defective, according to Kurachi et al. (1989) to evaluation of seed spacing, determining the percentage of spacing corresponding to classes: acceptable (0.5 X ref $\leq$ Xi < 1.5 X ref), double (Xi < 0.5 X ref) and failed (Xi $\geq$ 1.5 X ref), where X ref is the reference spacing.

On the essay performed, was used a seed distribution disk of 28 cells with corn.
The evaluated factors were arranged to allow the evaluation of variable effects both individually or in groups, being all data submitted to variance analysis, applying Tukey test at 5% of probability, to compare the averages.

The experiment was performed on a 3x2 factorial schema, with three displacement speeds, being them 3.0; 5.0 and 8.0 km h^{-1} (0.83; 1.39 e 2.22 m s^{-1}), and two tillage systems – direct and conventional seeding, in a randomized block design, with three repetitions, totalizing 18 experimental unities.

Results and Discussion

The sequence of results presentation and the discussions were made grouping the parameters by affinity and, when possible, on the chronological sequence of execution.

Table 1 presents the results of hourly (Hc) and specific consumption of fuel (Csp), operational consumption (Oc) and energetic consumption by worked area (Ect), on both seeding systems (SS), conventional (CS) and direct (DS) on the three displacement speeds (S) on corn culture seeding.

Table 1. Variance analysis expressed by F-test for variables hourly (Hc) and specific (Csp) consumption of fuel, operational consumption (Oc) and energetic consumption by worked area (Ect), on both seeding systems (SS), conventional (CS) and direct (DS) on the three displacement speeds (S) on corn culture seeding.

	Hc (L h^{-1})	Csp (g kW^{-1} h^{-1})	Oc (L ha^{-1})	Ect (kWh ha^{-1})
F-Test	MS	MS	MS	MS
SS	2.569**	339542.5**	7.089**	35.702**
S	7.829**	512160.2**	50.144**	0.004ns
SS x S	0.069ns	4751.448ns	0.519ns	0.224ns
Factors				
Seeding System	Average	Average	Average	Average
CS	7.20 b	1,300.22 a	10.45 b	6.64 b
DS	7.96 a	1,025.53 b	11.70 a	9.46 a
Speed	Average	Average	Average	Average
3.0 km h^{-1}	6.30 b	1,470.27 a	6.30 a	8.03 a
5.0 km h^{-1}	7.93 a	1,129.54 b	7.93 b	8.08 a
8.0 km h^{-1}	8.50 a	888.80 c	8.50 c	8.04 a
CV (%)	5.32	6.83	5.05	7.58

**Significant, at 1% probability level, by F-test; *Significant, at 5% probability level, by F-test; ns non significant. Averages followed by at least one letter do not differ statistically by Tukey test, at 5% probability level.

According to Table 1, it is possible to observe that the factors seeding system and speed had effect over the hourly fuel consumption. On direct seeding system the tractor used more fuel than on conventional seeding.

The hourly fuel consumption increased with the increase on displacement speed, not being observed statistical differences between 5.0 and 8.0 km h^{-1}.

OLIVEIRA (1997) also detected a 17% increase of hourly fuel consumption, with speed increase – 5.0 to 7.0 km h^{-1} – on seeding operation in two kinds of soil. MAHL (2002) also detected increase on the hourly fuel consumption of 30.5%, with the increase on speed – from 4.4 to 9.8 km h^{-1} – in the seeding operation on two kinds of soil. FULANI et al. (2007) studied the performance of a planter-fertilizer in direct planting with speeds of 4.5; 5.0 and 6.0 km h^{-1}, observing that, with speed increase, an increase on hourly fuel consumption also happened. MAHL (2006), MAHL et al. (2007) and SILVA (2009) also found effects of displacement speed over the hourly fuel consumption.

The increase on hourly fuel consumption may be explained due to the high exigency of the tractor-planter-fertilizer set due to speed increase.

Still on Table 1, it was observed that the factors seeding system and speed had affected the specific fuel consumption.

Fuel volume to generate the needed power on drawbar to traction the planter-fertilizer was different, comparing both kinds of seeding systems. On conventional seeding the tractor presented higher specific consumption than on direct seeding. MONTEIRO (2008) and NAGAOKA et al. (2002) observed a higher specific consumption on mobilized soil.

The specific fuel consumption fell with the increase on displacement speed, being observed statistical differences among all displacement speeds. With speed increase from 3.0 to 5.0 km h^{-1}, the specific fuel consumption went from 1,470.27 to 1,129.54 g kW^{-1} h^{-1}, representing a reduction of 30.17%. And with speed increase from 3.0 to 8.0 km h^{-1}, the specific fuel consumption reduced from 1,470.27 to 1,129.54 g kW^{-1} h^{-1}, representing a fall of 65.42%. MONTEIRO (2008) also detected reduction of specific fuel consumption with speed increase.

According to results on Table 1, it was verified that, among the conventional and direct seeding systems a significant difference was found for values of operational fuel consumption.

On the same way, the behavior of hourly consumption during direct seeding shows the highest value for operational consumption. There was a difference of 10.68% on the operational consumption increase under direct seeding system.

In relation to speeds, all of them differed statistically among them, propitiating a decrease on values of operational fuel consumption as displacement speed was increased. From 3.0 km h^{-1} to 8.0 km h^{-1}, there was a decrease of 68.70%.

SILVA (2009) and MAHL et al. (2004) found that this variable, in relation to the displacement speed of the tractor-planter-fertilizer set, influenced the operational fuel consumption, noting that with speed increase there was a significant reduction of this variable.

OLIVEIRA et al. (2000) observed significant difference on operational fuel consumption by varying the displacement speed, being the higher value found for 5.0 km h^{-1} of speed, that was the lower speed used. FURLANI et al. (2007) also verified reduction on operational fuel consumption from the lower to the higher displacement speed studied, presenting a significant difference.

Still on Table 1, on direct seeding a higher energetic consumption by worked area was observed. A percentage increase of 42.7% was found on energetic consumption by worked area on direct seeding system.

Factor speed did not cause significant effect on energetic consumption by worked area. The speed increase did not cause increase on energetic consumption by worked area.

Table 2 presents the results of average traction power (Pa), average power on bar (Pdba) and performance on drawbar (Pdb), on both seeding systems (SS) conventional (CS) and direct (DS) on the three displacement speeds (S) on corn culture seeding. According to Table 2, it was observed that factor seeding system statistically differed for the parameter average traction power evaluated.

Direct seeding system presented an average traction power significantly higher than the one on conventional seeding system. This happened, probably, due to higher resistance of soil to furrow openers for seeds and fertilizers on the planter-fertilizer.

The direct seeding system demanded, on average, 6.13 kN, while the conventional seeding system demanded, on average, 4.30 kN, resulting on a percentage difference of 42.56%.

Disagreeing with results obtained by CASÃO JÚNIOR (2000) and SIQUEIRA et al. (2001), and agreeing with results obtained by MAHL (2006), the speed increment did not result on increment of average traction power. MAHL et al. (2004),evaluating the energetic demand and efficiency of seed distribution of a planter-fertilizer for direct seeding, verified that, in relation to displacement speed, the traction power on two lower speeds (4.4 and 6.1 km h^{-1}) was similar, and those differed from the higher tested speed (8.1 km h^{-1}). SILVA (2000), also did not find any significant difference among treatments as a function of displacement speeds.

Still on Table 2, was observed that the conventional seeding system demanded 42.51% less power in relation to direct seeding.

Table 2. Variance analysis expressed by F-test for variables of average traction power (Pa), average power on bar (Pdba) and performance on drawbar (Pdb), on both seeding systems (SS) conventional (CS) and direct (DS) on the three displacement speeds (S) on corn culture seeding.

	Pa (kN)	Pdba (kW)	Pdb (%)
F-Test	MS	MS	MS
SS	14.991**	19.345**	56.392**
S	0.002ns	31.524**	91.896**
SS x S	0.094ns	1.705ns	4.969ns
Factors			
Seeding System	Average	Average	Average
CS	4.30 b	4.87 b	8.31 b
DS	6.13 a	6.94 a	11.85 a
Speed	Average	Average	Average
3.0 km h^{-1}	5.20 a	3.58 c	6.10 c
5.0 km h^{-1}	5.23 a	5.99 b	10.22 b
8.0 km h^{-1}	5.21 a	8.16 a	13.93 a
CV (%)	7.58	9.82	9.82

**Significant, at 1% probability level, by F-test; *Significant, at 5% probability level, by F-test; ns non significant. Averages followed by at least one letter do not differ statistically by Tukey test, at 5% probability level.

Speeds statistically differed among them; the average power parameter also differed among itself and variation of speed, with the speed increase causing gradual increase on the average power parameter. This result is similar to the ones obtained by OLIVEIRA (1997), SIQUEIRA et al. (2001) and MAHL (2002).

Knowing that power demand is a direct relation among traction power and speed, this experiment found that demand of power on drawbar was lower for the lowest speed. MAHL (2006) comments that, as displacement speed increased, a gradual increase on power demand also happened.

On the higher seeding speed, the power was 8.16 kW. With increase of displacement speed during seeding operation from 3.0 to 8.0 km h^{-1}, a percentage increase of 127.93% on average power in drawbar was perceived.

According to Table 2, the direct seeding system was the one where higher efficiency on drawbar was found – 11.85%. With speed increase there is an increase on drawbar efficiency. The higher speed presented the higher efficiency on drawbar for both seeding systems.

Table 3 presents results of effective field capacity (Ec), field efficiency (Fe), slip of wheelsets (Sw) and real displacement speed (Rs), on both seeding systems (SS) conventional (CS) and direct (DS) on the three displacement speeds (S) on corn culture seeding.

According to Table 3, is possible to see that the effective field capacity presented significant statistical difference among speed treatments, with the lower field capacity obtained on lower speed, who differed from others, being the highest effective field capacity – obtained on higher speed – of 1.02 ha h^{-1}.

The displacement speed increase on sowing operation from 3.0 to 5.0 and to 8.0 ha h^{-1}, allowed an increase in 65.32% and 127.29%, respectively, of effective field capacity.

As the speed increased, the effective field capacity presented directly proportional results. BRANQUINHO et al. (2004), studying three types of management with two displacement speeds for the planter-fertilizer (5.2 and 7.3 km h^{-1}), observed that the effective field capacity of the planter-fertilizer was higher on the highest speed. The effect of displacement speed over effective field capacity increase was also observed by LEVIEN et al. (1999), who obtained an average of 2.1 ha h^{-1} of effective field capacity for higher speed, while MARQUES et al. (1999) found 1.45 ha h^{-1}.

Still on Table 3, was observed that the speed factor for field efficiency evaluation parameter, presented a significant effect. It was observed that speeds of 3.0 and 5.0 km h^{-1} did not differ between them and presented the best values of field efficiency for the seeding work.

Table 3. Variance analysis expressed by F-test for variables effective field capacity (Ec), field efficiency (Fe), slip of wheelsets (Sw) and real displacement speed (Rs), on both seeding systems (SS) conventional (CS) and direct (DS) on the three displacement speeds (S) on corn culture seeding.

	Ec (ha h^{-1})	Fe (%)	S (%)	Rs (km h^{-1})
F-Test	MS	MS	MS	MS
SS	0.0003ns	5.5556ns	4.1713**	0.0098ns
S	0.4865**	283.9852**	1.4395**	15.0141**
SS x S	0.0005ns	8.2222ns	0.9457ns	0.0145ns
Factors				
Seeding System	Average	Average	Average	Average
CS	0.74 a	79.08 a	4.67 a	4.10 a
DS	0.73 a	77.97 a	3.71 b	4.06 a
Speed	Average	Average	Average	Average
3.0 km h^{-1}	0.45 c	82.78 a	3.97 b	2.48 c
5.0 km h^{-1}	0.74 b	82.20 a	3.86 b	4.11 b
8.0 km h^{-1}	1.02 a	70.58 b	4.75 a	5.65 a
CV (%)	2.61	3.00	4.73	2.61

**Significant, at 1% probability level, by F-test; *Significant, at 5% probability level, by F-test; ns non significant. Averages followed by at least one letter do not differ statistically by Tukey test, at 5% probability level.

Knowing that field efficiency is a direct relation between work width of planter-fertilizer and real displacement speed, this experiment found that field efficiency decreased with a speed increase from 3.0 km h^{-1} to 5.0 km h^{-1}, since the work width was the same for all speeds. It was observed that the higher speed (8.0 km h^{-1}) was the one who presented lower field efficiency. This may be justified due to the real work speed being well below the theoretical work speed.

SILVEIRA et al. (2006) observed during the seeding work an average efficiency of the tractor-planter-fertilizer set of 49.2%. The average operation speed was 3.4 km h^{-1} with a CV of 20.4%. The authors verified that operation speed varied a lot and differences were due to different soil conditions during sowing.

The values of field efficiency observed on this work stayed inside the ranges mentioned by some authors, for example MOLIN & MILAN (2002) mention that field efficiency on seeding work ranges from 65 to 85%. To SILVEIRA (2001) the range goes from 60 to 80%.

One goal of this work was to evaluate the performance of planter-fertilizer on direct seeding under changing displacement speeds, so that it was monitored during all displacement of the tractor-planter-fertilizer set on the experimental parcels.

During the performed essays, the speed values were lower than the ones displayed on the tractor cabin. The speeds 2A, 1B and 2B correspond to speeds of 3, 5 and 8 km h^{-1}, respectively, for a tractor without load with engine rotating at 2.100 rpm.

The coefficient of change on displacement speed monitoring was 2.61%, which can be considered as low.

According to Table 3, it is seen that the seeding system factor had significant effect on slip of wheelsets. On direct seeding, results showed an average slip lower than values found on conventional seeding for the tractor, therefore confirming interference of vegetation on the interaction wheelsets/soil. Similar results were found by Jesuíno (2007) and Vale et al. (2008).

Still on Table 3, is possible to verify that, slip of tractor wheelsets increased according to speed increase. Those results show that this evaluation parameter is directly related to the speed of effective displacement of the tractor and planter-fertilizer which is affected by wheelsets slip. Camilo et al. (2004) and Santos et al. (2008) also found similar results, where wheelsets slippage increased according to increase on displacement speeds.

Values of wheelsets slippage of tractor were below 4.75%. Those results were similar to the ones found by Mercante et al. (2005), who studied performance and distribution of seeds on two planters with two different displacement speeds. The author found slippage lower than 7% on all treatments and blocs, probably due to the excess of ballast used during the seeding operation.

Table 4 presents the analysis result of the longitudinal distribution variance of corn seeds, represented by the number of seed by linear meter, acceptable spacing between seeds, multiple spacing between seeds and failed spacing between seeds.

Table 4. Variance analysis expressed by F-test for variables seed by linear meter (Slm), acceptable spacing between seeds (As), multiple spacing between seeds (Ms), and failed spacing between seeds (Fs).

	Slm (seeds. m^{-1})	As (cm)	Ms (cm)	Fs (cm)
F-Test	MS	MS	MS	MS
SS	2.0000**	1.3888ns	2.7222**	2.0000**
S	1.1666**	2.1666ns	1.1666**	2.0000**
SS x S	1.1666**	1.7222ns	2.0555**	0.6666**
Factors				
Seeding system	Average	Average	Average	Average
CS	7.0 b	4.9 a	0.1 b	1.0 b
DS	7.7 a	5.4 a	0.9 a	0.3 a
Speed	Average	Average	Average	Average
3.0 km h^{-1}	7.2 b	5.7 a	0.2 a	0.3 b
5.0 km h^{-1}	7.8 a	4.5 a	1.0 a	1.3 a
8.0 km h^{-1}	7.0 b	5.3 a	0.3 a	0.3 b
CV (%)	4.55	15.13	66.67	70.71

**Significant, at 1% probability level, by F-test; *Significant, at 5% probability level, by F-test; ns non significant. Averages followed by at least one letter do not differ statistically by Tukey test, at 5% probability level.

As presented on Table 4, a significant effect occurred on factors seeding system, speed and interaction among seeding systems and speed over seed distribution per linear meter and ideal spacing between seeds. On direct seeding system, the average distribution was 7.7 seeds per linear meter and on conventional seeding 7.0 seeds. The planter-fertilizer was set to distribute 7.1 seeds per linear meter, on the direct seeding system was observed a percentage increase on the number of distributed seeds by linear meter of 8.33%.

There was a significant effect of factors seeding system, speed and interaction among seeding system and speed, over the number of seeds per linear meter, multiple spacing between seeds and failed spacing between seeds.

According to Vale et al., 2008; Mantovani et al., 1999, speeds over 0.32 m s^{-1} may hurt the distribution uniformity, because, with those peripheral speeds on the dosimeter disc, the seeds do not have enough time to fill all holes in the dosimeter disk, therefore failures will happen on distribution. But speeds under 0.29 m s^{-1} favor the whole filling of holes on the dosimeter disk, and may only cause problems when seeds have sizes much smaller than the disk holes. According to values presented on Table 4, it is possible to see that, according to the increase on peripheral speed of dosimeter disk there was reduction of acceptable spacing (ideal) between seeds. Therefore, the results are according to the theory proposed by the mentioned authors.

Conclusions

Among the studied seeding systems, the conventional seeding system was the one with better results.

Among the studied speeds, 8.0 0 km h^{-1} was the one with better performance.

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