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LONGITUDINAL DISTRIBUTION OF SEEDS UNDER THE ACTION OF DIFFERENT CONDUCTOR TUBES AND SOWING SPEEDS

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ABSTRACT

The objective of this study was to evaluate the distribution of longitudinal soybean seeds under the action of different sowing velocities and conductor tubes. The test was carried out on a sticky belt test, equipped with a seed meter, Selenium model, adjusted for seeding of 12 seeds m^{-1}, submitted to four different tubes and three sowing speeds at 5, 7 and 9 km h^{-1}, resulting in a completely randomized experimental design in a factorial scheme. Spacings between seeds were selected, classified as acceptable, misses and multiples, in addition to spacing variations coefficient. The data obtained were submitted to analysis of variance and the averages of the Tukey test levels of 5% error probability. The sowing speed only showed statistical differences for the spacing variables and the average deviation values while the conductor tubes showed distinct performance, with the Selenium tube being the one with the highest percentage of average spacings acceptable (98.5%) and smaller average values of spacing misses, multiples and coefficient of variation (Cve): 0.67; 0.68 and 18.4% respectively.

Palavras-chave:
Bancada simuladora
Coeficiente de variação
Espaçamentos
Plantabilidade

DISTRIBUIÇÃO LONGITUDINAL DE SEMENTES SOB AÇÃO DE DIFERENTES TUBOS CONDUTORES E VELOCIDADES DE SEMEADURA

RESUMO

O objetivo do trabalho foi avaliar a distribuição longitudinal de sementes de soja sob a ação de diferentes tubos condutores e velocidades de semeadura. O ensaio foi realizado em bancada simuladora de semeadura, equipada com um dosador de sementes pneumático, modelo Selenium, regulado para semeadura de 12 sementes m^{-1}, submetida à quatro tubos condutores e três velocidades de semeadura 5, 7 e 9 km h^{-1}, resultando em um delineamento experimental inteiramente casualizado em esquema fatorial. Foram avaliados os espaçamentos entre sementes, sendo estes classificados em aceitáveis, falhos e múltiplos, além do coeficiente de variação dos espaçamentos. Os dados obtidos foram submetidos a análise de variância e as médias comparadas pelo teste de Tukey ao nível de 5% de probabilidade de erro. As velocidades de semeadura apenas apresentaram diferença estatística para as variáveis espaçamentos múltiplos e coeficiente de variação, enquanto os tubos condutores apresentaram desempenho distinto, sendo o tubo Selenium o que apresentou maior porcentagem de espaçamentos médios aceitáveis (98,5%) e menores valores médios de espaçamentos falhos, múltiplos e coeficiente de variação (Cve): 0,67; 0,68 e 18,4% respectivamente.

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INTRODUCTION

The sowing process is one of the most important steps in the development cycle of an agricultural crop, and must be carried out in order to ensure the greatest possible uniformity in the distribution of seeds (ALONÇO *et al*., 2018). Seeders must be able to cut the plant cover on the ground in the same operation, to furrow and deposit seeds and fertilizers evenly, and close and compact the sowing furrow (SAVI *et al*., 2020).

Dias *et al*. (2020), emphasize that problems during sowing can occur due to the disorderly increase in operating speed and incompatible adjustments of the tractor-planter set, causing irregularities in the spacing between seeds/plants. The correct spacing between plants in the row, resulting from an adequate uniformity of seed distribution, allows the crop to express its best productive potential, avoiding energy waste and increasing the photosynthetic rate of the crop (MARQUES FILHO *et al*., 2020).

Zhai *et al*. (2019), point as determining factors for the quality of seed distribution, the dosing system and the process of driving the seeds to the ground, which are affected by the natural vibration of the machine during the sowing operation, and potentially aggravated by the increase in the operating speed. Mialhe (2012), defines the discharge of seeds released by the metering mechanism as a basic function of a sowing machine. According to Li *et al*. (2016), the seed driving or unloading mechanisms are mounted at the feeder outlet and their function is to guide the seeds smoothly to the sowing furrow.

Liu and Yang (2015) state that seed conductor tubes should be used to reduce the distance between the dosing point and the seed drop point, and the negative effects caused by the amount of kinetic energy accumulated in the dosing mechanism, thus reducing the variation of the horizontal speed of the seed caused by the different dosing speeds and the rebound effect, causing the seed to reach the soil with low speed, ensuring uniformity of distribution. According to Correia *et al*. (2020) and Carpes *et al*. (2017), if the metering mechanism is adjusted correctly, the effects of poor distribution may result from the rebound of the seeds in the conductive tube, caused by the increase in sowing speed.

Evaluating the effect of conductor tubes under different wear conditions on the longitudinal distribution of different corn seed formats, Kocher *et al*. (2011) found the lowest distribution irregularity results for the newer tubes, evidencing the importance of the condition of the inner surface of the tube in the distribution uniformity, which according to the authors should be smooth, without irregularities characteristic of rough surfaces, since the seeds come into direct contact with the tube during the path from the meter to the ground, and cannot face obstacles that change or impede their trajectory.

Considering that the seeders available in the machine market are mostly equipped with conductive tubes, the objective of this work was to evaluate the longitudinal distribution of soybean seeds under the action of different conductive tubes and sowing speeds.

MATERIALS AND METHODS

The experiment was carried out by the Grupo de Plantio Direto (GPD) team, at the Agroforestry Machinery and Tire Testing Center (NEMPA), belonging to the Faculty of Agronomic Sciences, of the São Paulo State University "Júlio de Mesquita Filho" (FCA/Unesp), Botucatu campus, São Paulo.

The experimental design adopted was a completely randomized design (DIC) in a 4 x 3 factorial scheme, with four different conductor tubes combined with three sowing speeds, totaling 12 treatments, with 20 replications each. The test was carried out on a simulator mat composed of a pneumatic metering mechanism, model Selenium, brand J.Assy, with a seed discharge area with 999.68 mm^2, coupled to a 0.45 meter height of the seed conveyor belt. Two three-phase induction electric motors with 0.25 kW of power at 1590 rpm were used, one for moving the conveyor belt while the other operated the seed meter. An electromechanical turbine was also used, responsible for the negative pressure (vacuum) to adhere the seeds to the pneumatic metering disc, with 0.37 kW of power.

To control and change the speed, a potentiometer was used connected to the analog input of inverters that changed the frequency of the motors, resulting in a change in the rotation of the dosing disk as well as the conveyor belt. To conduct the test, seeding was carried out on a simulator bench using four different conductive tubes (Figure 1), the T1 tube of the commercial brand J.Assy, model selenium, sold together with the seed doser, T2 and T3 of the brand commercial Jumil, models 27,49,097, 27,41,487 respectively and T4 of the brand Semeato, model 35120013, with all tubes submitted to three seeding speeds: 5. 7 and 9 km h^{-1}.

The metering mechanism was previously set to a sowing density of 12 seeds $meter^{-1}$, equipped with a 40-hole disk with a hole diameter of 4×10^{-3}. The seeds used in the test were the cultivar Neo 580 IPRO, from the company Neogen Seeds.

To characterize the length, width and height of the seeds, a sample of 50 seeds was randomly collected, they were placed on the bench, one by one, with the hilum facing up, then the length (L), width (W) and height (T) were measured with a digital caliper, manufactured by the company Jomarca, with a precision of 1×10^{-5} m. To evaluate the sphericity of the seeds (ϕ), the methodology described by Soyoye *et al*. (2018), where sphericity is given by the cube root of the product of multiplying the length (L), width (W), seed height (T), divided by L, exposed in equation 1.

$$\Phi = \frac{(LWT)^{\frac{1}{3}}}{L} \tag{1}$$

To obtain the repose angle of the seeds, a sample of seeds was slowly inserted into a box with dimensions of 0.3 x 0.385 x 0.08 m, in a way that allowed its fall and natural accommodation in the box (Figure 2), then, the angle of the ramp formed with the base of the box was calculated, according to the trigonometric relationship provided in equation 2, whose result comes from the tangent arc of the division between the height formed by the pile of seeds (h) and the length of the pile (L).

$$\alpha = arctg\left(\frac{h}{L}\right) \tag{2}$$

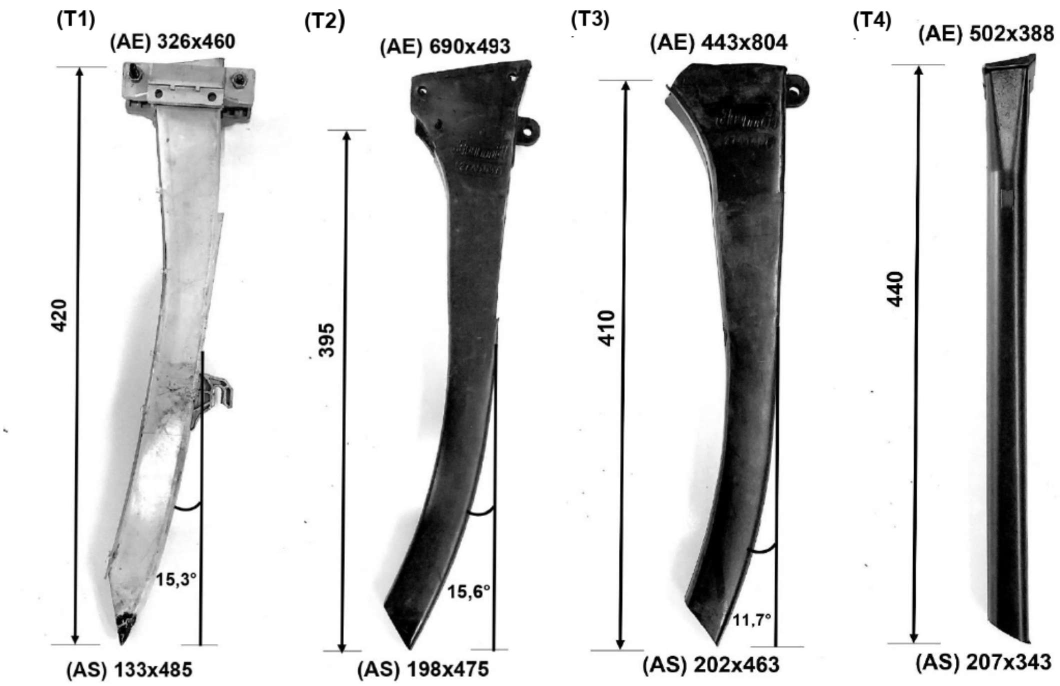

Figure 1. Seed conductors tubes and their dimensions in millimeters

The physical properties of the seeds are shown in Table 1.

The evaluation of the longitudinal distribution of seeds was carried out following the methodology proposed by Kurachi *et al*. (1989), in which the author classifies the spacings as acceptable, misses and multiples, for this, a millimeter tape was used to collect the spacing between the seeds. The spacings were collected for two consecutive meters in each repetition, totaling 40 meters of collection for each velocity and conductor tube. Considering sowing density of 12 seeds m^{-1}, the ideal spacing between the seeds is equal to 8.3 cm, so the spacings were classified as multiples when 0.5 times smaller, misses when 1.5 times longer and acceptable in the range between these minimum and maximum values, as shown in Table 2.

To evaluate the uniformity of seed distribution in the different treatments, the coefficient of variation of the spacings (Cve) was calculated, this parameter is used, according to Marques Filho *et al*. (2020), as a way of representing the dispersion of seed deposition (dp) as a function of an expected average value (X), within the tolerance interval,

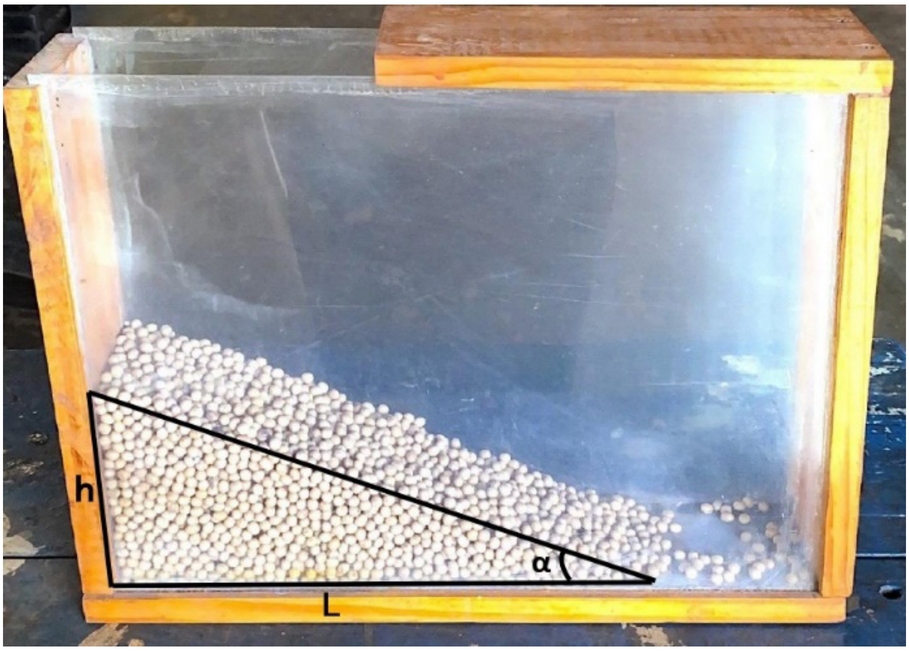

Figure 2. Box containing seeds for calculating repose angle

Table 1. Physical properties of the seeds

*P*hysical properties of the seeds	
Length (L)	6.90 mm
Width (W)	5.75 mm
Height (T)	6.49 mm
Sphericity (ϕ)	12.39 mm
Angle of repose (α)	24.96 °

Table 2. Classification of spacing from reference value

Classification of spacing	Spacing (cm)
Acceptable	$4.165 < X_{ref} > 12.495$
Misses	$X_{ref} > 12.495$
Multiples	$X_{ref} <4.165$

so that the coefficient of variation is a direct way of indicating the quality of seed distribution, as described in Equation 3.

$$CVe = \frac{dp}{x} x100 \tag{3}$$

The data obtained were submitted to statistical analysis of variance by the F test and the regressions were compared by the Tukey test at the level of 5% error probability.

RESULTS AND DISCUSSION

The results of analysis of variance of the longitudinal distribution of seeds and coefficient of variation of the spacings are presented in Table 3.

As indicated by the F test, no interaction was found between the factors leading tube and seeding speed (T x V) or significance for the speed factor, considering the variables acceptable and faulty spacings. Also considering the interaction, the F test respectively indicated a significance of 1 and 5% error probability for the multiple variables and Cve. All the variables analyzed presented significance at the level of 1% for the different conductive tubes, while for the evaluated speeds, no significance was determined for acceptable and faulty.

The results regarding the performance of the conductive tubes at different seeding speeds for acceptable spacings are shown in Figure 3.

Table 3. Analysis of variance of the longitudinal distribution of seeds and coefficient of variation of the spacings (CVe) as a function of the factors conducting seed tube and sowing speed

Fator	Variábles			
	Acceptable	Misses	Múltiples	CVe
	Teste F			
Seed tube (T)	20.74**	7.95**	27.95**	41.50**
Sowing speed (V)	2.43^{NS}	0.37^{NS}	4.16*	8.57**
T x V	1.82^{NS}	0.32^{NS}	2.85*	4.20**
EP	2.53	1.72	1.49	2.45
DP	11.30	7.69	6.67	10.98
DMS[1]	4.22	2.87	2.49	4.10
DMS[2]	5.34	3.63	3.15	5.19
CV %	12.38	21.18	16.84	38.92
Overall average	91.31	1.72	4.87	28.20

Significant at the level of P ≤ 0.05. ** Significant at the level of P ≤ 0.01. NS: not significant P ≥ 0.05. EP: Standard error. DP: Standard deviation. DMS1: Minimum significant difference between columns. DMS2: Minimum significant difference between lines. CV%: Coefficient of variation

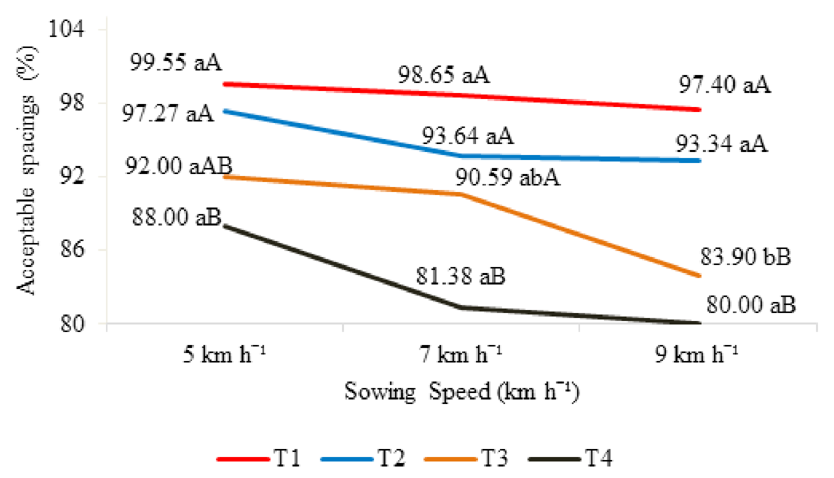

Figure 3. Acceptable spacings depending on the seeding speed and the conduction tube. T1: Selenium Conductor Tube; T2: Jumil Conductor Tube 27,49,097; T3: Jumil Conductor Tube 27,41,487; T4: Semeato conductor tube. Equal lowercase letters on the same line and capital letters between lines do not differ by Tukey's test (P≤0.05)

Although a reduction in acceptable spacing values was found (Figure 3) in all tubes, with increasing operating speed, no statistical difference was found between the speeds. The smallest reduction of acceptable was found in the sowing with T1, occurring a reduction of 2.15% and the biggest with T4, presenting a fall of 9.09%, all comparing the sowing at 5 km h^{-1} with the 9 km h^{-1}. The results corroborate Correia *et al*. (2020), who evaluated the longitudinal distribution of soybean seeds by conventional and titanium horizontal disc metering mechanism at different speeds, found that the increase in sowing speed is inversely proportional to the amount of acceptable spacing.

Among the seed conductor tubes, the highest average acceptable spacing value obtained, 98.5%, was for sowing with T1, which can be explained by the greater harmony of the doser/conductor mechanisms as they were designed to work together by the same manufacturer. The highest acceptable values between the tubes for T1, even with the increase in speed, it is possible to understand that there are certain limitations and points of attention in relation to the adaptation of conductive tubes.

The alternative tubes showed a directly proportional relationship with the average working angle, presenting 94.75%, 88.83%, 83.13% of acceptable, respectively for T2, T3, T4, which sowed at angles of 15.6°, 11 .7° and 0°. The result corroborates the results presented by Savi *et al.* (2020) confirming a positive influence of the tube angulation on the number of acceptable spacings, the greater the angulation, the greater the number of acceptable spacings, Carpes *et al*. (2017) found better distribution results for angles with an exit of 30°.

The results regarding the performance of the conductive tubes at different seeding speeds for the faulty spacings are shown in Figure 4.

In the percentage of faulty spacing (Figure 4) the conductive tubes differed statistically only at the 9 km h^{-1} speed, being possible to find a difference of 5.42 times between the highest value (8.4%) using T3 and the lowest value (1,55%), using T1. The lower percentages of failures for tubes 1 and 2 can be explained by the greater angulation of the two tubes, as found by Savi *et al*. (2017) and because they have shorter lengths, shortening the fall trajectory and improving distribution as described by Liu and Yang (2015).

All tubes had the percentage of flaws increased with seeding speed, even though no statistical difference was found for the variable in any of the conductors used, because it is a static test, that is, the closest to the ideal conditions, the distribution and conduction of seeds occurs without the natural vibrations of the machine that affect the distribution (Zhai *et al*., 2019), thus reducing the effects caused by the increase in speed.

The results regarding the performance of the conductor tubes in the different seeding speeds for the multiple spacings and coefficient of variation of the spacings are presented in Figures 5 and 6, respectively.

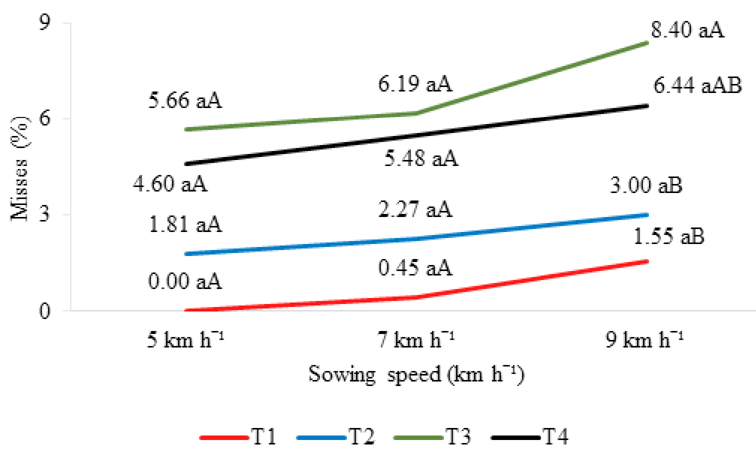

Figure 4. Misses spacings as a function of seeding speed and conductor tube. T1: Selenium Conductor Tube; T2: Jumil Conductor Tube 27,49,097; T3: Jumil Conductor Tube 27,41,487; T4: Semeato conductor tube. Equal lowercase letters on the same line and capital letters between lines do not differ by Tukey's test (P≤0.05)

For the variables multiple spacings and coefficient of variation of spacings (CVe), represented respectively by Figures 5 and 6, a significant difference was found between tubes. At the speed of 5 km h^{-1}, in both variables, T4 presented the highest value, differing from the other conductive mechanisms, being possible to observe a 74-fold increase in the percentage of multiples between T4 (7.4%), and the lowest percentage obtained (0.1%) for T1. Regarding the coefficient of variation, T1 also presented a lower index of multiples (13.5%), 36% lower than the index presented by T4 (36.58%), corroborating Savi *et al*. (2020), who found a double index and CVe 2.58 and 1.63 times higher for straight conductors compared to those with working curvature.

A directly proportional relationship was found between the speed factor and the multiple spacing and CVe variables. The highest speed increment for doubles index was found for T3, with a 50-fold difference between the lowest speed, 5 km h^{-1}, and the highest speed, 9 km h^{-1}. As for the CVe variable, the tube that was most influenced by the velocity was T3, which comparing the two extreme velocities, it was possible to observe an increase of 95.22% using the dosing mechanism. The sowing speed increases the horizontal speed of the seeds, causing a greater index of trajectory deviation

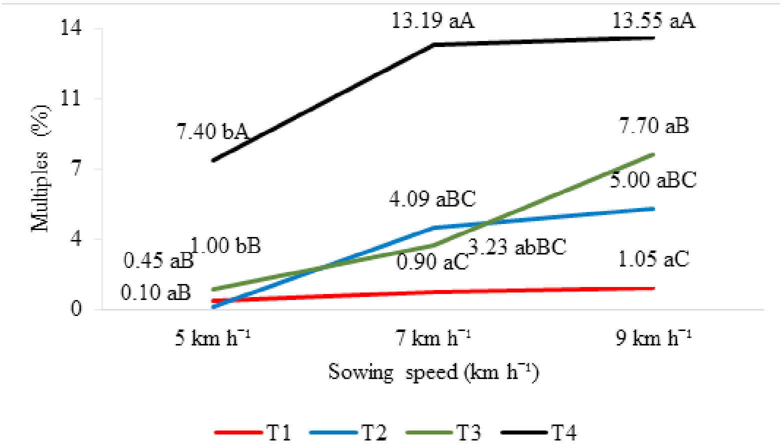

Figure 5. Multiple spacings as a function of seeding speed and lead tube. T1: Selenium Conductor Tube; T2: Jumil Conductor Tube 27,49,097; T3: Jumil Conductor Tube 27,41,487; T4: Semeato conductor tube. Equal lowercase letters on the same line and capital letters between lines do not differ by Tukey's test (P≤0.05)

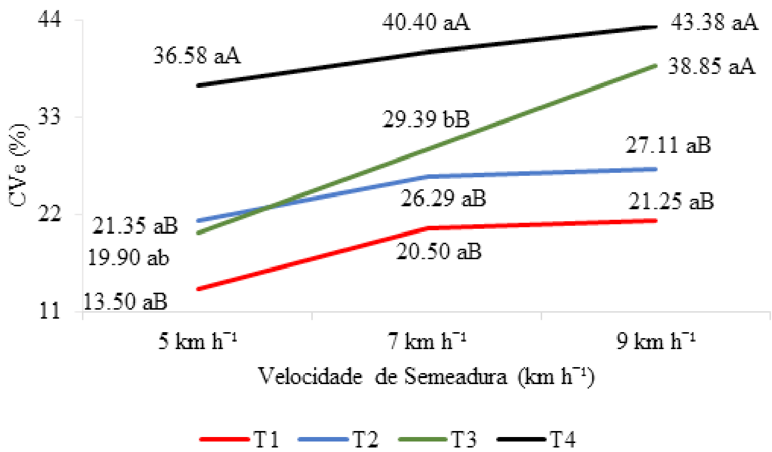

Figure 6. Coefficient of variation of spacing (Cve) as a function of sowing speed and the conduction tube. T1: Selenium Conductor Tube; T2: Jumil Conductor Tube 27,49,097; T3: Jumil Conductor Tube 27,41,487; T4: Semeato conductor tube. Equal lowercase letters on the same line and capital letters between lines do not differ by Tukey's test (P≤0.05)

inside the tube, causing multiple and flawed spacings, consequently increasing the irregularity of the distribution Carpes *et al*. (2017), Correia *et al*. (2020) and Lopes *et al*. (2022).

CONCLUSION

- The curvature of the conductive tube showed a direct relationship in seed distribution and sowing quality. The tube with 15.6° of working angulation presented better performance for the acceptable spacing indexes, multiple flaws and coefficient of variation of spacings. The increase in sowing speed caused a reduction in the number of acceptable spacings and an increase in the values of misses and multiples spacings and in the coefficient of variation.

AUTHORSHIP CONTRIBUTION STATEMENT

TAVEIRA, W.M.C.F.: Conceptualization, Formal Analysis, Project administration, Writing – original draft, Writing – review & editing; **SILVA, P.R.A.:** Conceptualization, Investigation, Supervision, Validation, Writing – review & editing; **LOPES, A.G.C.:** Conceptualization, Data curation, Formal Analysis, Methodology, Writing – review & editing; **SOUZA, A.A.R.:** Data curation, Investigation, Writing – review & editing; **CORREIA, T.P.S.:** Formal Analysis, Software, Writing – review & editing.

DECLARATION OF INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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