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Use of graphite in the distribution of rice seeds with constant flow seed metering device[1]

Uso do grafite na distribuição de sementes de arroz com dosador de fluxo contínuo

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HIGHLIGHTS:
The use of graphite decreased seed mechanical damage.
Regardless of roller exposition rate, seeding density did not change.
Graphite and the adequate roller exposition rate increase seeding efficiency.

ABSTRACT: The performance of the seed metering mechanism is evaluated according to the deposition uniformity during its operation and interference in the seed quality. The study aimed to assess the influence of graphite on the deposition homogeneity and the break index of rice seeds, distributed with a constant flow metering device with different exposition rates of the fluted roller. The rice seeds were treated with 4 g of graphite per kilogram and had a sowing density of 100 kg ha^{-1}. The completely randomized design was arranged in a double factorial scheme (2 × 5). The first factor was the use of graphite, and the second was the fluted roller exposition rate (20; 40; 60; 80; and 100%). The sowing density and the coefficient of variation were collected by gravimetry using a load cell. The use of graphite as a solid lubricant decreased the mechanical damage. Nevertheless, it also reduced the homogeneity in seed distribution. The increase of the roller exposition rate negatively interfered with the coefficient of distribution variation and positively with the break index of rice seeds, not influencing the sowing density. In this way, the use of graphite as a solid lubricant for sowing small grains distributed from the fluted rotor becomes promising.

Key words: *Oryza sativa*, seed drill, fluted roller, mechanical damage, sowing, deposition homogeneity

RESUMO: O desempenho do mecanismo dosador de semente é avaliado de acordo com a uniformidade da deposição ao longo da operação e sua interferência na qualidade das sementes. O objetivo do experimento foi avaliar a influência da utilização do grafite, na homogeneidade de deposição e no índice de quebras das sementes de arroz, distribuídas com dosador de fluxo contínuo sob diferentes taxas de exposição do rotor acanalado. As sementes de arroz foram tratadas com 4 g de grafite por quilograma de semente e densidade de semeadura de 100 kg ha^{-1}. O delineamento experimental foi inteiramente casualizado, em fatorial duplo (2 × 5), sendo o primeiro fator o uso do grafite e o segundo a taxa de exposição (20; 40; 60; 80 e 100%) do rotor. A densidade de semeadura e o coeficiente de variação foram coletados por gravimetria, com auxílio de célula de carga. A utilização de grafite como lubrificante sólido diminui os danos mecânicos, no entanto prejudicou a homogeneidade de distribuição das sementes. O aumento da taxa de exposição do rotor interferiu negativamente o coeficiente de variação da distribuição e positivamente sobre o índice de quebras das sementes de arroz, não alterando a densidade de semeadura. Desta forma, o uso do grafite como lubrificante sólido para semeadura de grãos finos distribuídos a partir do rotor canelado torna-se promissor.

Palavras-chave: *Oryza sativa*, semeadora, rotor acanalado, dano mecânico, semeadura, homogeneidade de deposição

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Introduction

The adequate deposition of seeds during sowing, regarding quantity and uniformity, is related to the performance of seed metering mechanisms (Maleki et al., 2006). This operation has a fundamental role in crop establishment because homogeneity in distribution interferes with the efficient use of the resources available to plants, permitting their maximal genetic potential (Baio et al., 2019; Pereira & Hall, 2019).

Constant flow seed drills are used to distribute tiny seeds, which volumetrically dose the seeds through fluted rollers, the opposite of precision seed drills (Kumar & Raheman, 2018). Distribution homogeneity of seeds must be measured in the deposition after the conductive tube, which is the last component of the seed drill acting on the distribution, resulting in the actual deposition in the sowing furrow (Al-Mallahi & Kataoka, 2016).

Studies by Kumar & Raheman (2018) and Liu et al. (2019) evaluated the deposition rate of seeds through optical sensors with infrared detection. Silva et al. (1998), while evaluating the performance of different seed metering devices with dryland rice seed distribution, reported a low mechanical damage rate using a fluted roller regarding the peripheral horizontal disk and the dosage cup.

The fluidity of seeds in the reservoir is directly related to the adherence to the metering components. Thus, it is necessary to adopt a solid lubricant to reduce the coefficient of friction inside the seed metering device (Hentschke, 2002). The use of graphite during the dosage of large seeds is widely studied. However, the efficiency of this technique during the distribution of small seeds still requires technical information.

Thus, the initial hypothesis of this study was that the use of graphite could favor the efficiency of the seed metering device based on the seed fluidity increase inside the reservoir. The study aimed to evaluate the influence of graphite on the rice sowing density regarding the deposition uniformity and the incidence of breaks under different exposition rates to the fluted roller.

Material and Methods

The experiment was carried out at the Federal University of Paraná, Curitiba, PR, Brazil (25° 41’ 29” S, 49° 24’ 19” W; altitude of 920 m asl).

The seed metering device (Figure 1) has a constant dosage flow with a polyethylene fluted roller with 12 flutes in a semicircle of 5.5 mm diameter, arranged helicoidally at a 7.0° angle.

The mechanism actioning was performed by the Gearmotor Sew Eurodrive® of 0.25 kW, managed through a frequency inverter Weg® CFW300. Thus, the rotational speed of the fluted roller is adjusted through the frequency emitted with a coefficient of determination (R^2) of 1.00, in which each hertz increase 0.76 rpm in the axis of the metering device.

The experiment was conducted in a completely randomized design arranged in a double factorial (2 × 5), with eight replicates. The first factor was the use or not of graphite as a solid lubricant. The second factor comprised

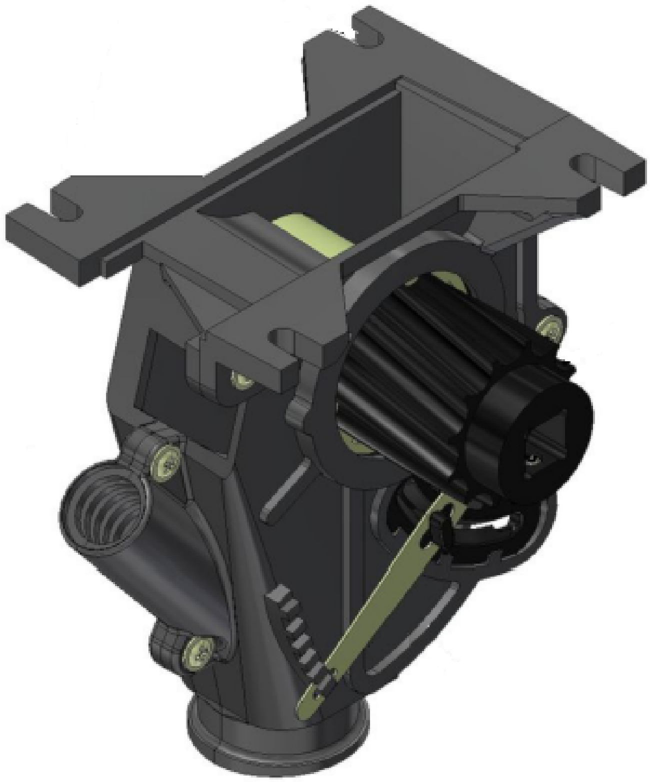


Figure 1. Constant flow seed metering device with helicoidal fluted roller

five exposition rates (20; 40; 60; 80; and 100%) of the roller to the grain mass, resulting in 80 experimental units. The data were collected for 120 s for each replicate, disregarding the initial and final 20 s.

The flow of the deposited seeds was adjusted through the longitudinal slide of the fluted roller, i.e., high exposition provides higher sowing densities (Besharati et al., 2019). The exposition rate was measured with a digital caliper with a resolution of 0.1 mm (NOVE 54®), resulting in openings of 14.8, 29.7, 44.5, 59.4, and 74.3 mm, respectively. Previous tests showed that each 0.7 mm (1% of roller exposition) equals the deposition of 0.24 g per turn, presenting a coefficient of determination (R^2) of 0.99.

Based on these data, a correlation between roller exposition and device rotational speed (was obtained by Victor™ digital tachometer model DM6236P) to provide the target sowing density of 100 kg ha^{-1}, according to Table 1. This density was adopted considering the space between the seeding rows of 0.18 m and the operational speed of 1.11 m s^{-1}.

During the experiment, rice seeds of the cultivar SCS 116 Satoru were used with 100% purity, 13.4% humidity, and

Table 1. Values of the seed metering device rotational speed and the frequency used to reach the target sowing density of 100 kg ha^{-1} in each fluted roller exposition

Roller exposition (%)	Deposition (g per round)	Rotational speed (rpm)	Frequency (Hz)
20	5.46	21.97	28.9
40	10.63	11.29	14.8
60	14.64	8.20	10.8
80	19.41	6.18	8.1
100	22.99	5.22	6.9

germination of 98.0%. The seed angle of repose, established by the inverse tangent of the height in proportion to the distance of the mass of the seeds deposited (Coetzee & Els, 2009), ranged between 40.52° without graphite and 36.35° with graphite.

The dimension characteristics of the seeds, such as length, width, thickness, and sphericity (Eq. 1), were analyzed in a sample with 100 seeds, as described by Soyoye et al. (2018) and presented in Table 2. The dimensions were obtained using the digital caliper previously described. The thousand-grain mass was evaluated in three samples with 300 seeds in a semi-analytical balance (model BK-5002 of the brand Gehaka LTDA®), with a measurement accuracy of ± 0.2 g. The specific mass was determined by the hectoliter weight (Botelho et al., 2018).

$$\Phi = \frac{(L \times W \times T)^{\frac{1}{3}}}{L} \tag{1}$$

where:

Φ - sphericity, %;
L - length, mm;
W - width, mm; and,
T - thickness, mm.

The break of pre-existing seeds and those generated during the deposition process were visually evaluated in three mass samples with 100 g for each treatment, as described by Reis & Forcellini (2009).

The seeds dosed by the fluted roller were conducted through the telescopic conductor to be deposited in a plastic container installed in the superior part of the load cell of the brand IWM, model SPL, with a capacity of 5 kg and a sensibility of 0.1%. This sensor was connected to a data acquisition system (DAS) of a printed circuit board with a data acquisition frequency of 1 Hz, and the values were transferred and stored in a hard drive (Jasper et al., 2016).

Each treatment data collection corresponds to the seed deposition in 400 s, selecting eight replications of 40 s. The variables evaluated based on the accumulated deposition mass in each replication were: sowing density (SD), coefficient of variation (CV), and break index (BI).

The normality evaluation of residues and homogeneity of variances were verified through Shapiro Wilk and Brown-Forsythe tests, respectively. Once the normality and homogeneity presuppositions were fulfilled, the data were submitted to the analysis of variance. The Tukey test was used for graphite means and regression analysis to evaluate the roller exposition rate using the program Sigmaplot® 12.

Table 2. Physical characteristics of the rice seeds of the SCS 116 Satoru cultivar

Characteristics	Unit	Mean	Standard deviation
Length	mm	10.02	0.48
Width	mm	2.48	0.11
Thickness	mm	1.97	0.07
Sphericity	%	36.54	1.14
1000-seed weight	g	30.20	0.38
Apparent specific mass	g L^{-1}	583.36	5.19
Mechanical damage	%	0.65	0.01

Results and Discussion

The summary of the analysis of variance and the test of means for the variables analyzed are shown in Table 3. The coefficient of variation for all variables was categorized as stable, according to the classification proposed by Ferreira (2018).

The analysis of variance demonstrated significant differences regarding the use of graphite and the exposition rate in the CV and break index (BI) results, besides the interaction for BI. Nevertheless, there was no statistical difference in sowing density.

The deposition rate remained constant due to the adjustment between the opening of the mechanism and rotation speed, differing from Reis et al. (2007) and Besharati et al. (2019), who altered these factors independently.

The coefficient of variation of seed deposition differed statistically, resulting in the addition of 2.45% using graphite. Different from Alonço et al. (2018), who concluded that using solid lubricants reduces the adverse effects of the coefficient of friction between seeds and the device, enhancing seed deposition in the furrow.

The curve of the CV of rice seeds deposition after the sowing density in the different fluted roller exposition rates to the grain mass is shown in Figure 2. It is observed a linear trend between the factors (roller exposition). Each 1% exposition rate increased 0.1047 times the CV, with R^2 greater than 99%.

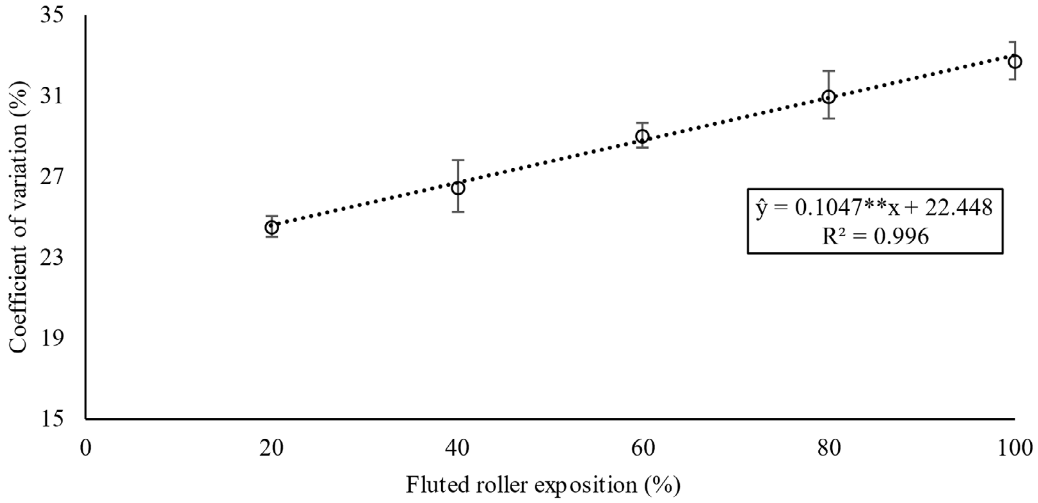
These results corroborate Karayel et al. (2006), Maleki et al. (2006), and Reis et al. (2007). They reported a reduction in the seed deposition uniformity at low rotation speed due to the sudden liberation of seed batches. Therefore, increases in the roller speed favor a more uniform distribution of the seeds in the sowing row.

Ozturk et al. (2012), while evaluating the deposition flow of wheat seeds, found that the length of the roller exposition and the axis rotation speed are factors that most influenced the

Table 3. Summary of the analysis of variance and the test of means of sowing density, coefficient of variation (CV), and break index of rice seeds with or without the use of graphite and fluted roller exposition rates

Use of graphite (UG)	Sowing density (kg ha^{-1})	CV (%)	Break index (%)
Without	101.21 a	27.52 b	2.63 a
With	101.12 a	29.94 a	1.19 b
Roller exposition rate (RE) (%)			
20	100.79	24.47	3.22
40	100.77	26.50	2.40
60	101.33	29.00	1.41
80	101.49	30.98	1.24
100	101.45	32.70	1.26
F-test			
UG	0.02^{ns}	8.764^{**}	982.69^{**}
RE	0.19^{ns}	13.234^{**}	292.18^{**}
UG x RE	0.42^{ns}	1.158^{ns}	69.96^{**}
Coefficient of variation (%)	3.17	12.70	6.61
Normality (SW)	0.83	0.051	0.33
Homogeneity (BF)	0.44	0.58	0.80

In each column, for each factor, means followed by the same lowercase letter do not differ between them by the Tukey test (p ≤ 0.05); F-test: analysis of variance (ANOVA); ^{ns} - Not significant; *, and ** - Significant at p ≤ 0.05, and p ≤ 0.01, respectively, by the F test; SW - Shapiro-Wilk normality test; and BF - Variance homogeneity test of Brown-Forsythe



** - Significant at p ≤ 0.01, by the F test; Vertical bar - Standard error

Figure 2. Coefficient of variation of rice seeds deposition in function of the fluted roller exposition rates to the grain mass

uniformity of the deposition flow. Thus, increasing axis rotation and length of roller exposition reduce the distribution CV.

After passing by the seed metering device, the samples collected had break index (BI) values significantly higher than the initial values of the seed lot used. It corresponded to 0.65% (Table 2), besides being statistically different regarding the use of graphite. While evaluating different seed metering devices, Almeida et al. (2003) did not find significant results regarding the generation of damages compared with the control, differing from these results. However, Correia et al. (2015), during the evaluation of sorghum seed distribution with constant flow seed metering devices, identified the promotion of damages during the sowing density.

The use of graphite as a solid lubricant reduced mechanical damage during the rice seed dosage, observed through a significant reduction in the BI in all roller exposition rates. On average, the use of graphite reduced the mechanical damage of seeds by reducing BI by 1.44%. The lowest mechanical damage results from reducing internal friction between seeds and the device components during the mechanism functioning (Hentschke, 2002).

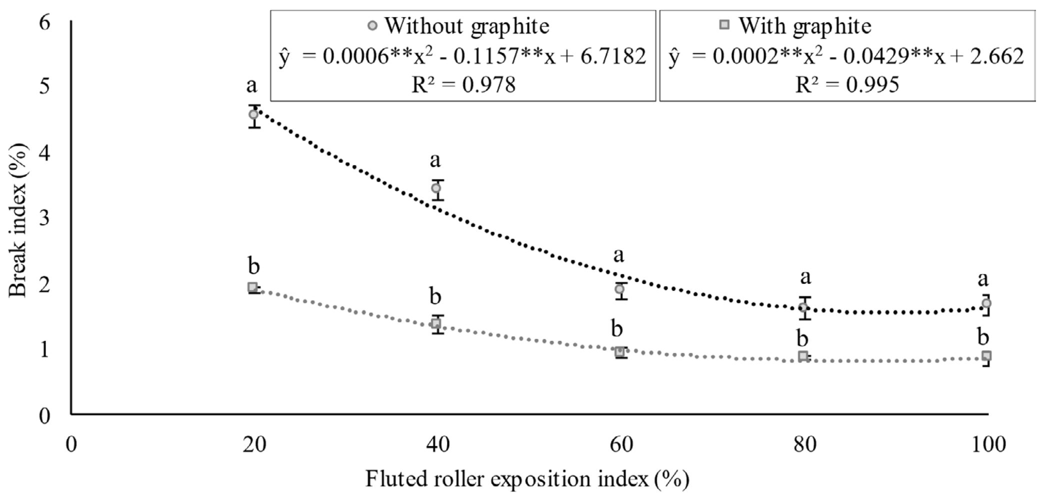
Concerning the interactions between the use of graphite and the fluted roller exposition rate on the break index of rice seeds, in Figure 3, the statistical regression model resulted in second-order polynomial curves for both cases.

The influence of graphite on the BI was statistically significant in all the fluted roller exposition rates. The differences were more significant at 20 and 40% of exposition, causing a reduction of 2.65 and 2.05%, respectively.

Without graphite, the BI of rice seeds has reduced statistically with the opening of the roller up to 60%. Without graphite, the BI of the lower opening rate had an addition of 2.89% regarding the maximal exposition. However, the addition with the use of graphite was 1.05%.

On average, both factors resulted in lower indexes of damages than those registered by Reis & Forcellin (2009) during the tests of a seed metering device prototype with a double-face vertical cylinder. The authors reported the general mean of mechanical damage to the seeds of 3.5%, being 2,9% the best result. The fluted roller seed metering device shows better results than the prototype developed by those authors regarding the damage level generated during its functioning.

According to the curves generated, a lower level of mechanical damage in the opening rate of 96.42% without graphite was observed, resulting in a CV of 32.5%. With graphite, the lower damage level occurred with an opening of



** - Significant at p ≤ 0.01 by the F test; Vertical bar – Standard error; At each percentage, means followed by the same letter do not differ between the use of graphite by the Tukey test (p ≤ 0.05)

Figure 3. Break index of rice seeds in function of the fluted roller exposition rates with and without the use of graphite

100% and, consequently, a CV of 32.7%. Nevertheless, both cases did not exceed the maximal limit of 45% used by Xi et al. (2020) when evaluating the efficiency of fluted roller seed metering devices in the distribution of wheat seeds.

Gutz et al. (2019) show that irrigated rice presents high phenological plasticity, providing statistically similar yields between the sowing densities of 60 and 150 kg ha^{-1}. Nevertheless, according to Chauhan & Opeña (2013), low sowing rates are only possible if the seed metering devices can distribute them evenly and with low levels of mechanical damage. Therefore, graphite and an adequate roller exposition rate are essential to promote sowing efficiency.

Given the influence of the factors evaluated, future studies sought to analyze these conditions for sowings with low density, such as when hybrid rice seeds are adopted. A condition in which the homogeneity of seed deposition and integrity of seeds are more critical due to the high investment in these crops.

Conclusions

1. The use of graphite reduced the distribution homogeneity, observed through the average addition of 2.62% in the coefficient of variation. Nevertheless, it minimized the break index regardless of the fluted roller exposition rates.

2. The increase in the roller exposition rate increased the coefficient of variation of distribution and decreased the break index. In this way, the use of graphite as a solid lubricant for sowing small grains distributed from the fluted rotor becomes promising.

3. The sowing density was not influenced by the two factors evaluated.

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