

Can dosing mechanisms affect the physical quality of corn seeds at different seeding speeds?

Nayara Francieli Parizotto¹, Aldir Carpes Marques Filho², Marcelo Munhoz Venâncio de Oliveira³, Flavia Luize Pereira de Souza¹, Paulo Roberto Arbex Silva¹

¹ Universidade Estadual Júlio Mesquita Filho, Campus de Botucatu, Botucatu, São Paulo, Brazil. E-mail: nayara-parizotto@hotmail.com, flavia.luize@unesp.br, paulo.arbex@unesp.br

² Universidade Federal de Lavras, Lavras, Minas Gerais, Brazil. E-mail: aldir.marques@gmail.com

³ Instituto Agrônomo de Campinas, Campinas, São Paulo, Brazil. E-mail: marcelomunhozagro@gmail.com

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ABSTRACT

Corn (*Zea mays* L.) is one of the main commodities of Brazilian agribusiness, however, the sowing operation of this crop still presents challenges related to the performance of the metering mechanisms and operational speed, since these can affect the physical quality of the seeds and impair germination. The aim of this study was to evaluate the physical quality of maize seeds as a function of different metering mechanisms and operational speeds in a controlled sowing trial. The experiment was carried out at the State University, UNESP/Botucatu-SP, using five commercial models of seed dosers at four operational sowing speeds. The results showed that the metering model and the operational speed directly affected the physical quality of the corn seeds, reducing on average 3.17% their germination power. The sowing speed did not directly affect the water content of the corn seeds; however, it proportionally increased the number of damages. Regardless of the metering mechanism, operating speeds between 4 and 6 km h⁻¹ provided less damage to the seeds.

Keywords: Plantability, Mechanical damage, Distribution systems, Seeding.

Mecanismos dosadores podem afetar a qualidade física das sementes de milho em diferentes velocidades de semeadura?

RESUMO

O milho (*Zea mays* L.) é uma das principais commodities do agronegócio brasileiro, entretanto, a operação de semeadura desta cultura, ainda apresenta desafios relacionados ao desempenho dos mecanismos dosadores e velocidade operacional, já que estes podem afetar a qualidade física das sementes e prejudicar a germinação. O objetivo deste estudo foi avaliar a qualidade física de sementes de milho em função de diferentes mecanismos dosadores e velocidades operacionais em ensaio controlado de semeadura. O experimento foi realizado na Universidade Estadual Paulista, UNESP/Botucatu-SP, utilizando-se cinco modelos comerciais de dosadores de sementes em quatro velocidades operacionais de semeadura. Os resultados mostraram que o modelo de dosador e a velocidade operacional afetaram diretamente a qualidade física das sementes de milho, reduzindo em média 3,17% o poder germinativo destas. A velocidade de semeadura, não afetou diretamente o teor de água das sementes de milho, entretanto, aumentou proporcionalmente o número de danos. Independentemente do mecanismo dosador, as velocidades operacionais entre 4 e 6 km h⁻¹, propiciaram menor intensidade de danos às sementes.

Palavras-chave: Plantabilidade, Dano mecânico, Sistemas de distribuição, Semeadura.



1. Introduction

The maize crop (*Zea mays* L.) has relevant importance for the Brazilian commercial balance. In the last harvest, the total area sown in the country was 4,542.5 thousand hectares, 4.5% above the previous harvest. Expected production should reach 24,979.1 thousand tons, a volume 1.0% higher than that achieved in the 2020/21 harvest (Conab, 2022).

The quality of the sowing operation, through the establishment of an adequate population of plants, is one of the main productive parameters for the maize crop (Arcoverde et al., 2016; Arcoverde et al., 2017). In order to achieve high yields, the characteristics of mechanized systems must be observed, using high standard seeds and adopting the operating speed relevant to each machine model (Bottega et al., 2014).

The qualitative physical attributes of seeds are related to water content, color, density, appearance, damage caused by insects or machines and infections caused by diseases. For Carvalho and Nakagawa (2012), approximately 40% of mechanical damage to seeds occurs during mechanized harvesting, but the sowing operation can increase this damage by 4%.

According to Andrade et al. (1999), mechanical damage can be classified as mild, intermediate and severe. Light damage is composed of small cracks in the seeds, without compromising their integrity, but some physiological processes are impaired. Intermediate damage includes seeds with damage that compromise the integrity or lack of small parts, but the material still has germination power. Severe damages are those that prevent seed germination.

One of the main variables interfering with sowing quality is the operational speed (Bertelli et al., 2016; Reynaldo et al., 2016) and the seed metering mechanism (Cortez et al., 2020). In Brazil, seeder-fertilizers use two main types of seed metering mechanisms, the horizontal disc and the pneumatic disc, the former being used in approximately 79% of machines (Francetto et al., 2015).

Horizontal mechanical feeders present greater contact intensity of the internal devices with the seeds, which can affect their germination power (Mialhe, 2012). Pneumatic feeders have high precision in seed dosing and a lower rate of mechanical damage to plant material (Bottega et al., 2018). Pneumatic feeders use a negative pressure system, in which a vertical disc rotates and retains the seeds in circular holes. (2018).

Understanding the effects caused by metering mechanisms and sowing speed on the physical structure of seeds is fundamental, as it allows the correct selection of equipment and planning of this mechanized operation. Therefore, the objective of this study was to evaluate the physical quality of maize seeds as a function of different metering mechanisms and operating speeds in a controlled sowing test system.

2. Material and Methods

The present study was carried out in the No-tillage Group (GPD), belonging to the Nucleus of Agroforestry Machines and Tires Testing (NEMPA), of the Faculty of Agronomic Sciences of the Universidade Estadual Paulista (UNESP) in the city of Botucatu. The sowing simulation was performed on instrumented benches, composed of seed conveyor belts, dosers and vacuum generation systems with variable adjustment in each subsystem. The simulators were equipped with three 1.5 kW three-phase electric motors and frequency inverters in each motor, allowing the variation of the motor rotation speed and, therefore, of the seeding mechanisms.

The first motor was coupled to the vacuum generating turbine for pneumatic metering, the second motor was installed in the seed metering mechanism and the third motor was responsible for moving the conveyor belt. For the mechanical feeders, the speed of the seed metering disc and the belt were controlled by motors 2 and 3. Five seed metering mechanisms were used for the tests, two pneumatic (P1 and P2) and three mechanicals (M1; M2 and M3), at four different sowing speeds: 4, 6, 8 and 10km h⁻¹, totaling 20 treatments with 4 replications, plus a control in the germination test that was not submitted to any metering mechanism.

For the controlled trials, corn seeds of the AL-Avaré Cati/2019 variety, subjected to standard laboratory tests in control treatment, without passing through the dosing mechanisms and, after being subjected to different operating conditions in the sowing simulators, were again evaluated in the laboratory to verify the influence of each device and speed on physical damage to seeds. The pneumatic feeders were J. Assy model Selenium (P1) and Jumil model Exacta. air (P2). The models and the sowing simulator system are described in Figure 1.

The horizontal mechanical feeders were: M1 – conventional model of the Agrodisco brand, equipped with a single-row disc, with 28 holes, 12.5 mm in diameter and a smooth bulkhead ring; M2 - Feeder model Titanium manufactured by the company J.assy, equipped with a single-row disc with 28 holes with an internal diameter of 11.0 mm and Rampflow technology (grooves on the side of the disc holes that help the seed placement); M3 - Plantsystem model dispenser with a single-row disc with 28 holes, 12.0 mm in size, and ring with 1.0 mm recess (Figure 2).

The procedure adopted in the controlled sowing tests consisted of removing homogeneous samples, composed of 1000 (thousand) corn seeds for each treatment. To count the seeds, an electronic device for counting seeds of the brand Plante+® was used. After counting and selecting the seeds, each metering mechanism was assembled in the sowing simulation system, samples of 1000 seeds were deposited in the simulator's reservoir boxes. Then, the treadmill was activated at speeds of 4, 6, 8 and 10km h⁻¹.

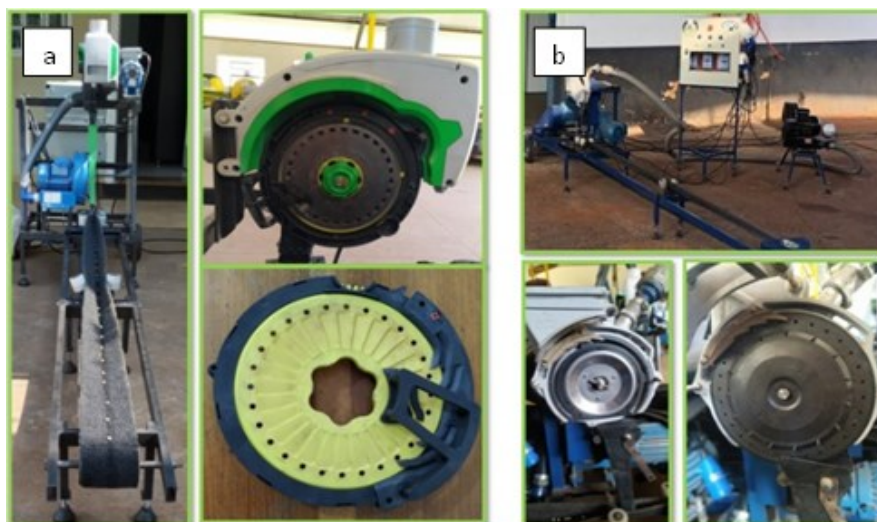


Figure 1. Sowing simulator systems with pneumatic feeders P1(a) and P2(b).



Figure 2. Seeding simulator system and details of mechanical feeders M1(a), M2(b) and M3(c).

After stabilizing the speed on the belt, the seed metering mechanism was activated at the corresponding speed, after passing through the metering selection mechanisms, the seeds were transferred to paper bags, duly identified and sent to the Seed Analysis Laboratory from the Plant Production Department at UNESP/Botucatu, where they were submitted to quality tests according to the Rules for Seed Analysis-RAS (BRASIL, 2009).

Water content, mechanical damage by the Iodine test and seed germination were evaluated in each treatment. To evaluate the water content and mechanical damage to the seeds it was used the methodology described by Borba et al. (1996), adopting the following criteria: no damage, to seeds that were not broken or with cracks in the embryo; mild damage, to seeds with damage to the endosperm; deep damage, to seeds with damage to the embryo with impaired germination.

The experimental design used was completely randomized (DIC), composed of 5 models of feeders and 4 operating speeds of the simulator conveyor. Test results passed Shapiro-Wilk normality tests; Bartlett and

Levene's test of homogeneity of variance; analysis of variance (ANOVA) and, when necessary, Tukey test at 5% probability. The results of seed damage as a function of speeds/feeders were submitted to Pearson's linear correlation tests. All tests applied were developed in the SISVAR statistical system (Ferreira, 2011).

3. Results and Discussion

The results of the average water content in the seeds showed that the effect of the different speeds was not significant in the comparison between the dosers, however there was a difference between them in relation to the control treatment (Table 1). The water content is one of the most relevant factors in the potential for seed fragmentation, since low water contents can increase the susceptibility to breaks and ruptures of the vegetative structure (Carvalho et al. 2012).

The results indicated a significant difference between the dosing mechanisms, with the lowest water content being observed for M2 (9.86%). The highest water

contents were found in M3 and P2 with 10.64% and 10.69%, respectively. Seeds with high water content are subject to “kneading” type of damage, on the other hand, in cases of low water content, “breakage” type of damage becomes more common (Carvalho et al. Nakagawa, 2012). Pneumatic feeders have greater seed retention capacity with less mechanical contact (Mialhe, 2012), this factor contributes to less damage with this feeder model. However, the results obtained in this study showed that the P1 pneumatic feeder affected the water content more severely than the M3 mechanical feeder, statistically equaling M1, a fact that contradicts the assertion that the pneumatic feeders are less harmful to the seeds in all situations.

The low performance of pneumatic feeders in the sowing operation was verified by Arcoverde et al. (2016), where a capability analysis was applied and it was found that the pneumatic seeder did not reach the goals established for the plant population, indicating the need for further investigations and monitoring of the operation. New models of seed feeders have been presented to the sowing market, however, operational and physical factors of the seeds can affect the performance of these systems.

Pereira et al. (2021) inferred that the shape of corn seeds can affect the quality of distribution in different feeders, with rounded seeds performing better in pneumatic feeders. Seeds that are too tight in the holes of the dosing mechanisms may suffer greater friction at the time of operation, which increases the rate of physical damage and mechanical injuries.

The location of the mechanical injury can determine the intensity of the damage to the seeds, and these can be considered mild or severe. Thus, if the shock occurs in the endosperm region and does not affect the embryo, it is possible that it does not significantly interfere with the physiological quality of the seed, in the case of mild damage. However, the closer to the embryo, the greater the chances that this seed will become unviable and the damage will become severe (Popinigis, 1985). Vale et al. (2010) inferred that horizontal honeycomb-type mechanical feeders have a high potential to cause damage to seeds as a result of abrasion and mechanical shocks caused by scrapers and ejectors (hammer-type), internal components of the selection and dosing system. The percentage of seeds with damage evidenced by the Iodine test can be verified in Figure 3

Table 1. Test of averages for seed water content as a function of different dosers and operational sowing speeds.

Water content (%)											
Speed (km ¹)	dosing system										
	M1	M2	M3	P1	P2	averages					
Control						11.10					A
4	10.18	9.80	10.60	10.33	10.70	10.32					B
6	10.28	9.80	10.55	10.35	10.48	10.29					B
8	10.58	9.85	10.75	10.08	10.78	10.41					B
10	10.35	10.00	10.68	10.20	10.80	10.41					B
Measuring Meters	10.34	ab	9.86	c	10.64	a	10.24	b	10.69	a	
Overall average	10.50										
CV (%)	3.05										

Averages followed by the same capital letters in columns and lowercase in rows not differ from each other by the Tukey at 5% of probability. M1= conventional mechanical system; M2= titanium mechanical system; M3 - plantsystem feeder; P1= selenium pneumatic system; P2= jumil pneumatic system); Control (seeds did not go through any metering mechanism)

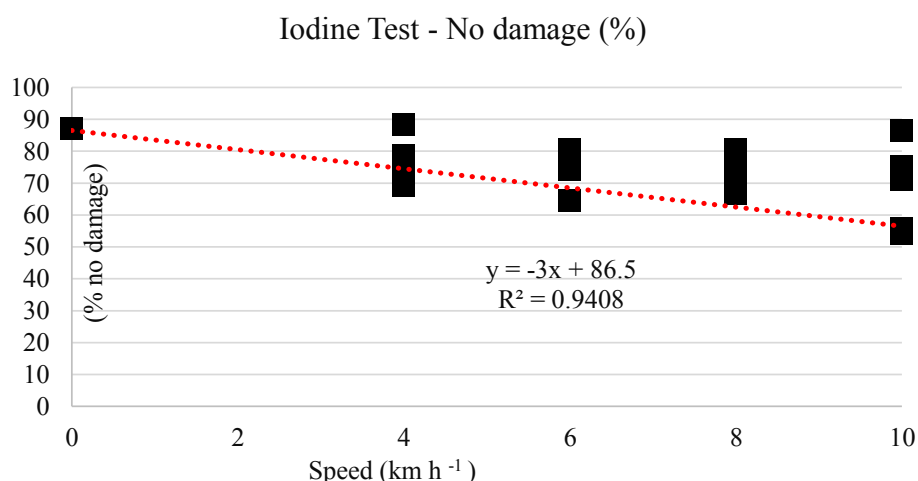


Figure 3 . Physical quality test (Iodine) for corn seeds - no damage.

In Figure 3 the percentage of seeds without damage increases as the operational speed decreases. The negative angular coefficient presented for the equation of the straight line, with an adjustment of $r^2=0.94$, indicates that the increase in speed has a behavior inversely proportional to the presence of undamaged seeds. Marques Filho and Ventura (2021) inferred that increasing sowing speed can affect ear formation and decrease corn productivity with the use of mechanical feeders. Fernandes, Tejo and Arruda (2019) concluded that increasing maize sowing speed directly affects the rate of faulty and double spacing and substantially reduces crop productivity.

The results of this study showed that the operating speed can increase seed damage, thus contributing to the reduction of crop uniformity and productivity, a fact that is based on the work of (Bertelli et al. 2016, Cortez et al.,2020). The figure 4 describes the percentage of light damage to corn seeds as a function of sowing operational speed. The maximum light damage rate obtained was 35% for a speed of 10 km h^{-1} . The lowest light damage rates were obtained at the speed of 6 km h^{-1} , followed by the speed of 4 km h^{-1} , indicating that these speeds are more recommended for the sowing process, regardless of the metering model used. Alonço et al. (2015) found an increase in sowing variability with increasing operating speed in a controlled trial.

In mechanical or pneumatic feeders, the selection of the disc-seeding ring set can interfere with the quality of distribution and the presence of damage to the seeds (Marques Filho et al.,2020). In the present study, the dispensers were selected with technical criteria of compatibility of the devices with the seeds, however, the disc models and slightly different orifice diameters, may have exerted an influence on the occurrence of severe damage. The severe damage index

showed greater variability in the data in relation to the increase in operational speed, and the best performance obtained was in the speed condition at 4 km h^{-1} , where the percentage of damage remained below 10% (Figure 5).

Garcia et al. (2011) found that the increase in travel speed, increased the slippage of the seeder wheels, reduced the effective field capacity and planting depth, which increased the unevenness of the operation. It was found that, for the condition of severe damage, the highest speeds affected the physical quality of the seeds, and the different technologies in feeders can increase the damage to the plant material at the time of sowing. The results obtained collaborate with those presented by (Fernandes et al., 2019; Garcia et al., 2011).

Bottega et al. (2018), comparing pneumatic and horizontal feeders, found a higher emergence speed index (IVE) for the pneumatic system, which, according to the authors, occurred because the feeder mechanism is less aggressive with the propagating material, when compared to the horizontal system. However, regardless of the metering model used, the authors found that the increase in speed generates non-uniform sowing, a fact that corroborates the results of the present research.

Seed germination in the laboratory, after passing through the metering mechanisms at different speeds, can be seen in Table 2. The control treatment, which did not undergo any metering mechanism, represents the maximum germinative potential of the seeds before the sowing operation. There was a significant difference between the average germination of the control treatment and the averages at different speeds, however, in relation to the speeds, there was no difference between the averages, a fact that indicates the dosing factor as the main component for the reduction of germination power.

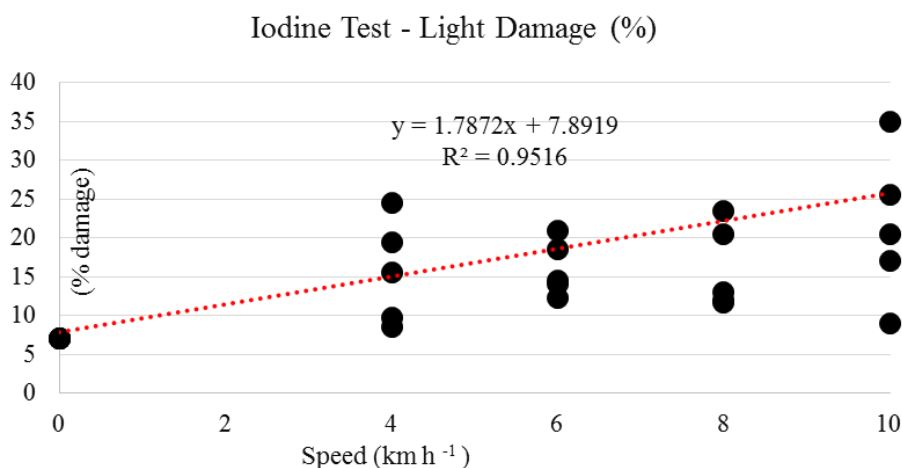


Figure 4. Physical quality test (Iodine) for corn seeds - light damage

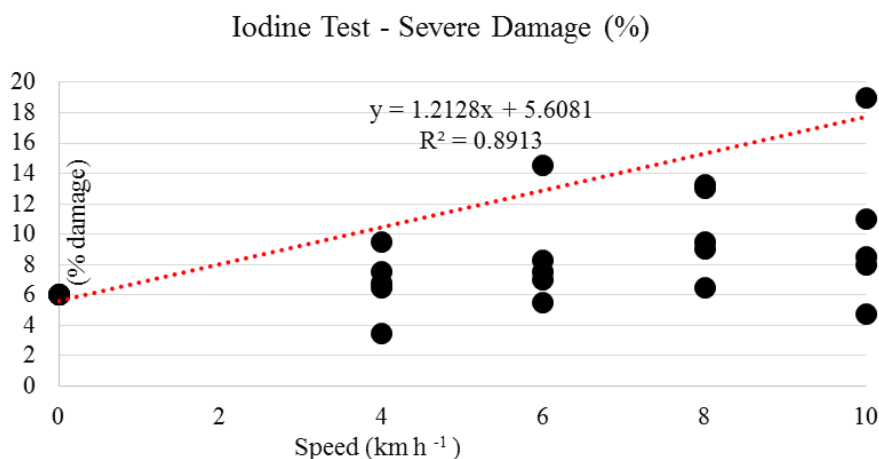


Figure 5. Physical quality test (Iodine) for corn seeds - severe damage

Table 2. Seed germination test in each treatment.

Speeds (km h ⁻¹)	dosing system					averages		
	M1	M2	M3	P1	P2			
Control	97.00	97.00	97.00	97.00	97.00	97.00	A	
4	93.50	95.00	91.50	93.50	91.00	92.90	B	
6	91.50	93.50	95.00	91.50	94.00	93.10	B	
8	93.50	96.00	91.50	92.00	93.50	93.30	B	
10	94.00	93.00	93.50	93.00	93.00	93.30	B	
Measuring Meters	93.90	ns	94.90	ns	93.70	ns	93.40	ns
general average	93.92							
CV (%)	3.60							

Averages followed by the same capital letters in columns and lowercase in rows not differ from each other by the Tukey at 5% of probability. M1= conventional mechanical system; M2= titanium mechanical system; M3 - plantsystem feeder; P1= selenium pneumatic system; P2= jumil pneumatic system); Control (seeds did not go through any metering mechanism) – ns * not significant at 95% probability.

In the average germination of the control treatment, used as reference, there was a reduction in germination power of 3.09; 2.16 and 3.4% in M1, M2 and M3, respectively. For pneumatic systems, the reductions were 3.71 in P1 and 3.4% in P2. The mechanical system M2 presented the best performance in relation to the reduction of the germinative power of the seeds, even surpassing the two pneumatic dosing technologies.

Considering the general average of the treatments in relation to the average of the control, there is a reduction of 3.17% of the germinative power of the seeds due to the passage through the dosing mechanisms. Garcia et al. (2011) found a 2.7% reduction in seed germination when passing through different metering mechanisms compared to seeds that did not pass through such devices. The authors did not find any difference in speeds in relation to the germination percentage, but it was evident that the metering mechanism affected the germination power of corn.

4. Conclusions

Feeders can affect the physical quality of seeds as a function of operational speed, reducing their germination power by an average of 3.17%. The increase in sowing operational speed does not directly affect the water content of the corn seeds, however, it proportionally increases the number of light and severe damages to them. Regardless of the metering mechanism, operating speeds between 4 and 6 km h⁻¹, provided less damage to the seeds.

Authors' Contribution

Author Nayara Francieli Parizotto contributed with the idealization, collection of seeds for the physical and physiological tests performed on the seeds, with the writing and review of the article, as well as for the statistical analysis. Aldir Carpes Marques Filho contributed to the writing, review, data analysis and statistics of the article.

Marcelo Munhoz Venâncio de Oliveira, contributed with the reading of the physiological tests carried out on the seeds, with the review and interpretation of the article into English. Flávia Luize Pereira de Souza, contributed with the reading of the physiological tests performed and with the review of the article. Paulo Roberto Arbex Silva, contributed to the idealization of the article.

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