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ORIGINAL ARTICLE

# Impact of on-farm and industrial treatments on seed longitudinal distribution for soybeans[1]

## Distribuição longitudinal de sementes de soja com tratamento industrial e on-farm

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*HIGHLIGHTS:*

*On-farm treatment resulted in seed spacing closest to the desired target.*
*Seeds treated with both phytosanitary measures and graphite displayed a more homogeneous longitudinal distribution.*
*Pneumatic seed metering proved effective across all treatments.*

**ABSTRACT:** Adequate seed placement is essential for consistent crop emergence and initial growth. Pneumatic seed metering systems offer superior longitudinal seed distribution accuracy compared to traditional methods, yet certain factors can influence this precision. For instance, seed physical properties may be altered by phytosanitary treatments applied either on-farm or industrially. This study examined the effects of phytosanitary treatment type and graphite addition on soybean seed deposition using an electric-driven pneumatic feeder under simulated sowing conditions. Seed distribution was monitored with an optical sensor. Four treatment groups were established: untreated without graphite, untreated with graphite added, on-farm treated with graphite, and industrially treated with graphite. Parameters assessed included average spacing between seeds, coefficient of variation, precision index, multiple and failed spacings, and percentage of acceptable spacing. Results indicate that prior seed treatment does not significantly affect overall planting accuracy. However, seed spacing varied between the untreated and on-farm treated groups, with the latter demonstrating closer proximity to optimal values. Both on-farm and industrial treatments yielded more uniform seed deposition, as indicated by a lower coefficient of variation. Regardless of seed treatment, the pneumatic feeder consistently performed effectively.

**Key words:** *Glycine max*, sowing, pneumatic seed metering, graphite

**RESUMO:** A deposição adequada de sementes tem grande importância na uniformidade da emergência e no desenvolvimento inicial das culturas. Uma maior precisão na distribuição longitudinal de sementes é possível com mecanismos dosadores de sementes pneumáticos em relação aos convencionais, mas existem alguns aspectos que afetam essa precisão. Por exemplo, a qualidade física das sementes pode ser impactada pelo seu tratamento fitossanitário, que pode ser feito na propriedade ou na indústria. Nesse contexto, este estudo investigou o impacto do tipo de tratamento fitossanitário e do uso de grafite na deposição de sementes de soja por meio de dosador pneumático com acionamento elétrico em bancada estática, simulando a semeadura e monitorando a distribuição das sementes com sensor óptico. As sementes foram submetidas a quatro tratamentos distintos: sem grafite, sem tratamento com adição de grafite, tratamento on-farm com adição de grafite e tratamento industrial com adição de grafite. Foram estudados o espaçamento médio entre deposições, coeficiente de variação de semeadura, índice de precisão, espaçamentos múltiplos e falhas e percentual de espaçamento aceitável. Os resultados indicam que o espaçamento adequado no plantio não é significativamente impactado pelo método de tratamento prévio das sementes. O espaçamento entre sementes diferiu entre os tratamentos sem grafite e pelo tratamento on-farm, sendo este último mais próximo do ótimo e o tratamento sem grafite mais distante do espaçamento ideal. Um coeficiente de variação de semeadura mais baixo indica que a deposição uniforme foi alcançada com os procedimentos on-farm e industriais. Independentemente do tratamento de sementes, o dosador pneumático demonstrou eficácia.

**Palavras-chave:** *Glycine max*, semeadura, dosador pneumático, grafite

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## INTRODUCTION

Soybean (*Glycine max*) is the world's primary oilseed, with 337.14 million tons cultivated across 122.68 million hectares in the 2019/20 growing season (USDA, 2020). Beyond domestic consumption, soy is crucial for international trade and is a foundation for biofuels, oils, and animal feed. Brazil produced 155.3 million tons during the 2022-2023 harvest (CONAB, 2024), and is projected to contribute approximately 163 million tons to the global soybean yield of 410.6 million tons in 2023-2024 (USDA, 2023).

Optimal planting and uniform plant spacing are pivotal for early crop success and influence overall yield (Pereyra et al., 2022). Pneumatic metering systems have emerged as a high-precision method for seed distribution (He et al., 2022).

Seed quality significantly impacts crop field performance, necessitating treatments to enhance seed health (Molin et al., 2021). These treatments can be applied at various stages, including commercial seed processing, industrial seed treatment (IST), or on-farm application, potentially altering the seed's physical properties (Afzal et al., 2020).

This study aims to assess the impact of seed treatment type, specifically IST and on-farm treatments, on longitudinal seed deposition.

## MATERIAL AND METHODS

Soybean seed deposition with industrial seed treatment (IST) and on-farm treated seeds was evaluated in a laboratory in Curitiba, PR, Brazil (25° 41' 29" S, 49° 24' 19" W; altitude 920 m), using a static sowing bench as described by Savi et al. (2020). This bench allows simultaneous installation of multiple metering systems and simulates various operational conditions.

The Selenium Electric (J. Assy®), a pneumatic feeder with an electric motor, was used. It featured a J. Assy® disk with 55 4.0 mm holes, along with a singulator and ejector. Seed metering operated under a vacuum of 4.98 kPa, generated by an IBRAM (Brazilian Machinery Industry®) model CR-3 radial compressor with a maximum airflow of 0.022 $m^3$ $s^{-1}$ and a vacuum capability of 12.75 kPa.

An external source powered the seed metering's electrical system, converting 110 V to 24 V, the system's operating voltage. The power supply also adjusted the voltage and current to the feeder.

Savi et al. (2023) determined the optimal sowing speed to be 7 km $h^{-1}$, based on the relationship between the voltage supplied and the RPM measured by a Victor® DM6236P digital tachometer. The desired seed deposition rate required an optimal RPM of 39,375, calculated from the number of holes on the seeding disk and the seeds deposited per disk rotation, achieved with 6.71 V and 1.36 A supplied to the feeder.

The experimental bench was linked to a data acquisition system (DAS) through a PCB designed in Proteus 8.1 software (Labcenter Electronics, UK) and produced on an LPKF Protomat 93s milling machine. This board connects to an AT Mega 328 microprocessor (Atmel®), which includes eight analog inputs, 14 digital inputs/outputs programmable via software, and a USB for communication and power.

Operating at 16 MHz with a 10-bit analog-to-digital converter on the Arduino platform, the microprocessor's data collection frequency was set at 1 Hz, synchronized with seed passage detected by optical sensors connected to the DAS. Data was uploaded and stored on a hard drive (Jasper et al., 2016).

Seed distribution dynamics were analyzed using a PM 400 optical sensor (Dickey John®) positioned in the seed conductor tube's middle region, part of the metering mechanism. The device, composed of an infrared light emitter and receiver, detects seeds as they interrupt the light beam, allowing precise event timing. Gierz et al. (2015) confirmed the sensor's 99% accuracy in seed detection.

Seed sizes were measured using the approach by Soyoye et al. (2018), and a BK-5002 semi-analytical balance (Gehaka Ltda®) determined the mass of 1,000 grains from three samples of 300 seeds each.

Control measurements revealed that the average dimensions of the seeds were 6.42 mm in length, 5.88 mm in breadth, and 5.30 mm in thickness, with a sphericity of 91.59 and a mass of 150.025 ± 1.55 g for a thousand grains.

For the on-farm treated seeds, the average measurements were 6.47 mm in length, 5.98 mm in width, and 5.40 mm in thickness. These seeds had a sphericity of 91.23 and weighed 156.663 ± 1.37 g per thousand grains.

IST-treated seeds displayed average dimensions of 6.49 mm in length, 6.07 mm in breadth, and 5.37 mm in thickness, with a sphericity of 91.59 and a mass of 158.075 ± 1.39 g per thousand grains.

Graphite was applied at a rate of 4 g $kg^{-1}$ of seed to enhance seed mobility. According to Savi (2023), using the angle of repose measurements, this graphite dosage significantly improved the fluidity of the soybean seeds.

Soybean seeds of the BMX ZEUS 55I57 RSF IPRO cultivar were used in the trial, adhering to purity and germination standards, distributed at a sowing density of 272,000 seeds per hectare, with approximately 8.17 cm between seeds and 45 cm between rows.

Four treatments were compared: seeds treated industrially by Seeds Ross using STANDAK® TOP with added polymers and drying powder; on-farm treated seeds using STANDAK® TOP according to the product leaflet; untreated seeds of the same cultivar with added graphite; and untreated seeds without graphite.

The experiment was conducted in a completely randomized design with six replicates and 250 consecutive spacings as the experimental unit. Data collection lasted until 2,000 seeds were deposited, with samples taken from the middle of each batch for statistical analysis.

Variables analyzed to assess the homogeneity of longitudinal seed deposition included the percentage of acceptable, multiple, and failed spacings, the seeding coefficient of variation, the precision index, and the average spacing between deposits. Seeder performance was evaluated using criteria detailed in Table 1 (ISO 7256/1, 1984; Aykas et al., 2013).

According to Cay et al. (2018), the Precision Index (PI) measures the variability of seed distribution relative to theoretical spacing (Eq. 1), excluding doubled and uneven depositions. Higher PI values indicate greater unevenness in

**Table 1.** Limiting criteria for seeder performance classification

| Spacing (%) | | | Classification |
|---|---|---|---|
| As | $D_D$ | Ud | |
| >98.6 | <0.7 | <0.7 | Excellent |
| >90.4 a 98.6 | ≥0.7 a <4.8 | ≥0.7 a <4.8 | Good |
| ≥82.3 a ≤90.4 | ≥4.8 a ≤7.7 | ≥4.8 a ≤10.0 | Regular |
| <82.3 | >7.7 | >10.0 | Unsatisfactory |

As - Acceptable spacing; $D_D$ - Doubled deposition; Fd - Uneven deposition

distribution compared to the desired spacing. It should not exceed the 29% upper limit suggested for precision seeders (Kachman & Smith, 1995).

$$PI = \left(\frac{\sigma}{Xop}\right) \times 100$$

where:

PI - precision index (%);
σ - standard deviation of the acceptable spacing (m); and,
Xop - optimal spacing (m).

The collected data underwent normality testing (Shapiro-Wilk) and variance homogeneity assessment (Brown-Forsythe). Data that did not meet normality were transformed using the Box-Cox procedure. Once these criteria were met, the data was subjected to analysis of variance, and means were compared using the Tukey test at $p \leq 0.05$, employing the R software (R Core Team, 2023).

## RESULTS AND DISCUSSION

Table 2 presents the results from the analysis of variance and mean tests for seed deposition data. All parameters studied demonstrated normality of residuals (Shapiro-Wilk) and homogeneity of variance (Brown-Forsythe).

The treatment without graphite resulted in an average spacing 0.73% smaller compared to On-Farm, which was close to the ideal 8.17 cm spacing. However, seeds treated solely with graphite or IST did not show any significant differences from the first two treatments.

These results may be due to variations in seed shape and size. Seeds treated with IST, On-Farm, and graphite have larger dimensions. Specifically, the On-Farm treatment shows less uniformity and adhesion of treatment particles, according to Reis et al. (2023). This affects the seed interaction with the deposition tube during sowing, prolonging deposition time and impacting the longitudinal seed distribution, leading to wider average spacings (Li et al., 2021).

Moreover, internal friction between seeds in the reservoir can be influenced by their physical characteristics, chemical treatments, and the roughness of the surfaces involved in the process. Prior studies, such as Badua et al. (2019), emphasize assessing the minimum angle of repose for each seed condition and treatment before sowing, which can affect spacing differences observed across treatments.

Regarding double seed deposition, no significant differences were observed between the treatments, contradicting findings by Badua et al. (2019) which suggested that solid lubricants like graphite could reduce friction between seeds and metering mechanism components, thereby improving seed separation and reducing equipment wear.

No significant differences were found in failed and acceptable spacings across treatments, aligning with Alonço et al. (2018), who also reported no significant differences in seed distribution based on phytosanitary treatment type. All evaluated treatments demonstrated similar precision levels, without significant deviations.

The trial also revealed that seeds treated solely with graphite or untreated seeds exhibited higher seeding coefficients of variation. In contrast, IST and On-Farm treated seeds showed a more uniform distribution, as evidenced by lower variation coefficients, suggesting greater uniformity in measured attributes and less variability relative to the mean. This uniformity can be attributed to the physical changes from seed treatments, which not only improve phytosanitary properties but also enhance seed size and weight, aiding in stand establishment accuracy (Taylor, 2020).

The precision index (PI) was consistently low across all treatments, staying within the maximum limit of 29% set by Kachman & Smith (1995).

Given the consistent results for acceptable, double, and uneven spacings and a low PI, the metering system could be classified as precise. This accuracy is crucial as it ensures consistent seed dispersal along the sowing line, facilitating a uniform and optimal stand. Supporting research by Xing et al. (2020) confirms this high precision, showing that seed spacing remains within acceptable limits despite minor fluctuations.

**Table 2.** Synthesis of the statistical results regarding seed deposition

| Treatment | Average spacing | Doubled | Uneven | Acceptable | SCV | PI |
|---|---|---|---|---|---|---|
| Normality - SW | 0.655 | 0.570 | 0.198 | 0.406 | 0.525 | 0.667 |
| Homogeneity - BF | 0.887 | 0.900 | 0.573 | 0.412 | 0.764 | 0.804 |
| F test | 4.941** | $1.928^{ns}$ | $1.598^{ns}$ | $1.898^{ns}$ | 3.064* | $1.375^{ns}$ |
| CV (%) | 0.35 | 92.04 | 40.93 | 1.01 | 5.50 | 1.49 |
| Means | (cm) | (%) | (%) | (%) | (%) | (%) |
| Without graphite | 8.09 b | 0.13 a | 1.73 | 98.14 | 18.98 a | 18.29 a |
| With graphite | 8.11 ab | 0.20 a | 2.13 | 97.67 | 18.70 a | 18.05 a |
| Industrial | 8.13 ab | 0.33 a | 2.67 | 97.00 | 17.82 b | 18.01 a |
| On-farm | 8.15 a | 0.47a | 2.80 | 96.73 | 17.68b | 18.18 a |

Shapiro-Wilk normality test: SW ≤ 0.05 = non-normal data distribution and SW > 0.05 = normal data distribution. Brown-Forsythe variance homogeneity test: BF ≤ 0.05 = heterogeneous variances and BF > 0.05 = homogeneous variances. $^{ns}$ = non-significant; * ($p \leq 0.05$) and ** ($p \leq 0.01$). CV % - coefficient of variation; PI - distribution variability as a function of the theoretical spacing. Means followed by the same letter within columns do not differ from each other by Tukey's test ($p \leq 0.05$)

## CONCLUSIONS

1. Seed spacing variations were observed only between untreated seeds without graphite and those treated On-Farm.
2. Phytosanitary treatments (both industrial and On-Farm) led to reduced seeding coefficients of variation during deposition, with no significant differences between the two treatments.
3. Although there were differences in acceptable seed spacing across treatments, all demonstrated uniform distribution and precision with the pneumatic metering mechanism.

**Authors' contributions:** The authors collaborated on research design, data collection, data analysis and interpretation, manuscript preparation, literature review, work supervision, and administration throughout the study.

**Supplementary documents:** This research does not include any supplementary data.

**Conflict of interest:** The authors declare no conflicts of interest, financial or otherwise, that could have influenced the development or execution of this work.

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