Ciência e Agrotecnologia
SCIENCE AND AGROTECHNOLOGY

Ciência e Agrotecnologia, 47:e013622, 2023
http://dx.doi.org/10.1590/1413-7054202347013622

Agricultural Sciences
eISSN 1981-1829

Treatment technologies for soybean seeds: Dose effectiveness, mechanical damage and seed coating

Tecnologias de tratamento de sementes de soja: Assertividade de doses, danos mecânicos e o recobrimento das sementes

Leandro Vilela Reis[1], Everson Reis Carvalho[1*], Venicius Urbano Vilela Reis[1], Amanda Carvalho Penido Nardelli[1], Dayliane Bernardes de Andrade[1], Adhemar Oliveira Junior[2]

[1]Universidade Federal de Lavras/UFLA, Departamento de Agricultura/DAG, Lavras, MG, Brasil
[2]Syngenta, Seedcare Institute, Holambra, SP, Brasil
[*]Corresponding author: eversoncarvalho@ufla.br
Received in September 30, 2022 and approved in March 2, 2023

ABSTRACT

Seed treatment is an important procedure in soybean cultivation and is currently performed in two ways: industrial seed treatment (IST), performed by the seed companies industry, and *OnFarm* treatment, performedby the producer. The objective of this research was to compare the influence of industrial and *OnFarm* soybean seed treatment technologies, including the machines and processes, on the occurrence of mechanical damage and the functional quality of treatment. Soybean seeds were subjected to phytosanitary treatments with different processes and machines: (1) industrial treatment with a batch process; (2) industrial treatment with a continuous flow process, (3) *OnFarm* continuous flow treatment with dosage distribution via fixed-volume doser and seed mixing via worm screw; and (4) controlrepresented by untreated seeds. The occurrence of mechanical damage was evaluated by the sodium hypochlorite test. The functional quality of the treatments was analyzed by seed coating, determined by means of digital image processing; particle detachment (dust-off); and dose effectiveness of thiamethoxam, determined by high-performance liquid chromatography (HPLC). The treatment of soybean seeds in batch or continuous flow industrial systems ensures better seed coating, greater dose effectiveness, less particle detachment and a lower occurrence of mechanical damage compared to *OnFarm* application technology. The digital processing of high-resolution images is efficient for quantifying the coating of soybean seeds by phytosanitary products. Seed coating is directly related to dose effectiveness.

Index terms: IST; *OnFarm*; digital image processing; HPLC; dust-off.

RESUMO

O tratamento de sementes é um procedimento importante na cultura da soja, atualmente realizado de duas maneiras: tratamento industrial de sementes (TSI), realizadoem instalações de empresas produtoras de sementes, e o tratamento *OnFarm*, realizado sob responsabilidade direta do produtor. O objetivo desta pesquisa foi avaliar a influência das tecnologias de tratamento de sementes de soja, envolvendo máquinas e processos com tratadoras industriais e *OnFarm*, sobre ocorrência de danos mecânicos e a qualidade funcional do tratamento. As sementes foram submetidas aos tratamentos fitossanitários com diferentes processos e máquinas: (1) tratadora industrial com processo de tratamento por batelada; (2) tratadora industrial com processo de tratamento por fluxo contínuo, (3) tratadora *OnFarm* de fluxo contínuo, distribuição das dosagens via dosador fixo volumétrico e mistura nas sementes via rosca sem fim e (4) controle, sementes não tratadas. Foram analisadas a incidência de danos mecânicos pelo teste de hipoclorito de sódio e a qualidade funcional do tratamento com análises de recobrimento das sementes por processamento digital de imagens, desprendimento de partículas (Dust-off) e assertividade da dose de tiametoxam por HPLC – High-Performance Liquid Chromatography. O tratamento de sementes de soja em tratadoras industriais de batelada ou de fluxo contínuo, asseguram recobrimento mais eficiente das sementes, maior assertividade da dose, menor perda de aderência de partículas do produto aplicado e menor incidência de danos mecânicos em comparação à tecnologia de aplicação *OnFarm*. O processamento digital de imagens de alta resolução é eficiente para quantificação do recobrimento de sementes de soja com produtos fitossanitários. O recobrimento de sementes apresenta relação direta com a assertividade de dose.

Termos para indexação: TSI; *OnFarm*; processamento digital de imagens; HPLC; dust-off.

INTRODUCTION

Seed treatment (ST) is an important technology for protecting seeds during storage and the initial phase of seedling development against pathogens and pests in the seeds and soil. In addition to controlling pathogen transmission by seeds, ST efficiently ensures adequate plant populations when edaphoclimatic conditions are less favorable to the rapid germination and seedling emergence, leaving seeds exposed for a longer time to fungi and pests (Brzezinski et al., 2015). ST with fungicides may favor the initial development of soybean seedlings, especially under soil water restriction conditions (Carvalho et al., 2022).

ST alone is not a guarantee of sanitary and physiological quality since several compounds and products can be used to treat soybean seeds and different spray volumes can be applied; such factors can positively or negatively affect the physiological performance of seeds (Carvalho et al., 2022; Santos et al., 2018). In addition to these factors, product application to the seeds can be performed using different procedures, which can be broadly divided into two categories. In the first approach, commonly called *OnFarm*, the process is performed under the farmer's supervision and with generally less accurate equipment. Farmers adopt different ST strategies in the *OnFarm* system, mainly including conventional continuous flow systems that use fixed-volume dosers, popularly called "cups", to adequately distribute the chemical product and a worm screw to mix the products with the seeds (Ludwig et al., 2011).

With the modernization of agriculture, industrial seed treatment (IST) has recently been adopted, in which treatment is performed in the seed companies, followed by seed storage until sowing. In IST, high-tech machines are used to improve the treatment process; when performed correctly, this approach can favor adequate product doses and a more uniform product distribution (Brzezinski et al., 2015; Nunes, 2016). This type of treatment has become more widely adopted in the soybean production chain, and several companies offer this technology (Carvalho et al., 2020; Ferreira et al., 2016).

IST can be performed with continuous flow or batch treaters. In batch systems, the seeds are placed inside a rotating chamber, and the treatment solution is sprayed from a central location through a "spin" distributor, thus covering the seeds. The result is a precise treatment load as a function of the volume of syrup/solution applied. Conversely, in industrial treaters with continuous flow technology, seeds are transported with adequate and constant flow in a primary distributor for spraying the seed treatment syrup/solution, and the seeds are gently mixed in a secondary distribution device to ensure that all seeds are coated with the same amount of syrup (Platzen, 2010). However, the potential advantages of this treatment process require clarification through more scientific studies to quantify the process and propose future improvements.

The treatment of soybean seeds with phytosanitary products is increasing over time, given the importance of this technique to ensure an adequate and uniform stand establishment, which is one of the basic premises of high productivity. A current relevant topic of interest is the equipment for the application of these phytosanitary treatments, specifically related the occurrence of mechanical damage and the functional quality of the treatment, such as dose effectiveness, seed coating and particle detachment. To address these topics, new procedures and the use of image analysis may be useful and efficient. However, scientific studies are lacking, regarding the applicability of image analysis to this topic.

Thus, the objective of this study was to evaluate the effects of industrial and *OnFarm* soybean ST procedures on the occurrence of mechanical damage, dose effectiveness, particle detachment (dust-off) and coating (evaluated by digital image processing), i.e., the functional quality of soybean seed treatment.

MATERIAL AND METHODS

The experiment was conducted in three locations. The first site was a seed production plant, Agro-Sol Sementes, located in the state of Mato Grosso - MT, municipality of Campo Verde, where seed treatments were performed on an industrial scale. Later, the functional evaluations of the seeds were conducted at the Central Seed Laboratory of the Federal University of Lavras (Universidade Federal de Lavras, UFLA), Lavras - MG and at the Seedcare Institute of Latin America - Syngenta, Holambra - SP.

Soybean seed lot, cultivar Monsoy M8644IPRO, was subjected to different phytosanitary product treatment technologies. These technologies included (1) industrial treatment with a batch process (Machine model: Arktos 150K); (2) industrial treatment with a continuous flow process (Machine model: VHS Seed mix 20T); and (3) continuous flow *OnFarm* treatment (Machine model: Grazmec MTS60) with dose distribution via fixed-volume dosers and seed mixing via worm screw. A control (4) represented by untreated seeds. Seeds were treated with phytosanitary products, including fungicides, insecticides and a nematicide, with the Fortenza® Elite commercial recipe: Maxim Advanced® (metalaxyl-M + thiabendazole + fludioxonil) at a dose of 100 mL 100 kg^{-1} seeds, Cruiser

350 FS® (thiamethoxam) at 200 mL 100 kg^{-1} seeds, Fortenza 600 FS® (cyantraniliprole) at 60 mL 100 kg^{-1} seeds, Avicta 500 FS® (abamectin) at 100 mL 100 kg^{-1} seeds, and polymer (Biocroma® red) at 100 mL 100 kg^{-1} seeds. The total spray volume was 560 mL 100 kg^{-1} seeds.

After treatment, the seeds were placed in reinforced paper bags and sent to UFLA and the Seedcare Institute for the following analyses:

Occurrence of mechanical damage by the sodium hypochlorite test

It was estimated using the sodium hypochlorite immersion test. A total of 100 seeds were used for each replicate of the treatments. Seeds samples were placed in petri dishes and immersed in 0.13% sodium hypochlorite solution for 10 minutes. After this period, seeds were distributed on paper towels, and the number of seeds with swollen, broken and/or loose seed coats, corresponding to mechanical damage, was registred. Results were expressed as the percentage of seeds with mechanical damage (Krzyzanowski; França-Neto; Costa, 2004).

Seed coating by image analysis

High-resolution images were captured using a Ground Eye® system, version S800, consisting of a capture module that has an acrylic tray and a high-resolution camera and integrated software for evaluation. The percentage of seed coating for each treatment was evaluated by image analysis.

The soybean seeds were inserted into the tray of the capture module to obtain high-resolution images, and 100 seeds were analyzed for each replicate of the treatments. The system was calibrated with respect to background color; the CIE L*a*b* color model was applied with an L* parameter range of 0.0 to 100.0, a* parameter range from -18.8 to 41.2 and b* parameter range from -56.1 to -6.5. The minimum discard size was 0.30 cm^2, and interior filling was selected. This model was developed after several pretests.

After calibration of the background color, the images were analyzed using the Color: Dominance tool, and the sum of the percentages of Color: Red Dominance and Color: Pink Dominance of the analyzed seed samples was considered the percentage of seed coating with the treatment products. The colors were defined in relation to the colors of the ST products.

Particle detachment (dust-off)

Prior to the test, the seeds were stored for 48 hours at 20 °C and 50% relative humidity. After this period, a Heubach D.38679 A Langelsheim dust meter was used, following the methodology of the European Seed Treatment Assurance -ESTA, 2022). Seed samples of each replicate of the treatments were evaluated with the following parameters: equipment operating time: 2 minutes; sample size: 100 g of seeds; and air flow: 20 liters per minute. A 6 cm diameter microfiber filter was placed in the filter holder, and the setup was weighed on a precision scale to five decimal places. The drum was loaded with 100 g of seeds, and the equipment was turned on. The rotary movement of the drum and the friction of the seeds agitated by the baffles in this compartment resulted in the release of dust particles. These particles were aspirated by the air flow through the filter (20 liters per minute, duration 2 minutes), and the detached dust was retained in the filter. At the end of the established time, the filter setup and filter holder were weighed again, and the mass of detached dust particles was estimated by weight difference. The results are presented in g 100 kg^{-1} seeds, according to Equation 1.

Detachment of particles

$$\left(g100\ kg^{-1}\right) = \left(\left(W1 - W0\right) \times 100.000\right) Ws^{-1} \tag{1}$$

where:
W1: weight of the filter holder with fiberglass filter after the test (g);
W0: weight of the filter holder with fiberglass filter before the test (g);
Ws: weight of treated seeds (g).

Quantification of the active ingredient thiamethoxam by HPLC (dose effectiveness)

High-performance liquid chromatography (HPLC) was used to quantify the dose effectiveness (concentration) of thiamethoxam, an insecticide present in all treatments (except in the control seeds, which were untreated). After preliminary testing, a dose of 0.7 g of thiamethoxam per kg of seeds was established, corresponding to a dose of 200 mL of the commercial product Cruiser 350 FS 100 kg^{-1} seeds, which was considered the desirable dose. The samples were analyzed in an Agilent 1260 Infinity II HPLC system with a solvent compartment system, quaternary pump, injector, chromatographic column, VWD detector and computer with analytical software.

To prepare the samples for analysis, 50 g of soybean seeds were weighed in triplicate for each replicate of the treatments. For extraction, the samples were placed in 100 mL of ultra-purified water and shaken for 15 minutes at 200 rotations per minute in a shaker. The washing solution was filtered through qualitative filter paper, and the filtrate was collected in a 125 mL Erlenmeyer flask. A 4-mL aliquot of the filtrate was transferred to a 100-mL flask. The volume was completed with ultrapure water. The samples were filtered with a 5 mL syringe and 0.22 µm filter, the contents were transferred to identified microtubes, and injections and readings were performed. To quantify the insecticide thiamethoxam by HPLC, the following parameters were used as established by the Laboratory of the Seedcare Institute of Latin America - Syngenta: C18 chromatographic column: Zorbax ODS column with 4.6 mm internal diameter, 250 mm length, and 5 µL film or similar; mobile phase: water: acetonitrile (70:30); mobile phase flow rate: 1.0 mL min^{-1}; wavelength: 255 nm; injection volume: 10 µL; and column temperature: 40 °C. The sample retention time was approximately 3.7 minutes. The software automatically calculated the results in g kg^{-1}, which were then transformed into percent accuracy as a function of the desirable dose, 0.7 g kg^{-1} thiamethoxam.

Design and statistical analysis

A completely randomized statistical design (CRD) was used, with 4 treatments (batch IST, continuous flow IST, *OnFarm* fixed-volume dosing and control - no treatment) and six replicates. The data were subjected to analysis of variance (ANOVA) with the statistical software SISVAR® (Ferreira, 2019) at 5% probability by the F test, and the means were compared using the Tukey test ($p < 0.05$).

RESULTS AND DISCUSSION

Figure 1 shows the visual aspects of untreated seeds (white) and seeds treated with different industrial and *OnFarm* technologies. Visual analysis is still used to classify treatment efficiency in many companies, but this parameter can often be inaccurate and difficult to standardize. Image analysis can improve the efficiency of treatment quality classification regarding seed coating.

Figure 2 shows the average percentage of occurrence of mechanical damage as a function of treatment technology. No difference was observed between the IST and control seeds, for both the batch and continuous flow systems. However, higher occurrence of mechanical damage was observed in seeds subjected to *OnFarm* treatment with the fixed-volume feeder and worm screw, with an increase of 4.5 percentage points (p.p.) compared with the control. This increase was related to the simpler technology, i.e., the worm screw, in the *OnFarm* system. Equipment developed for IST has technologies that enable effective treatment in a shorter seed handling time and thus minimize the occurrence of mechanical injuries in the seeds, as found in the present study.

Figure 1: Visual appearance of the soybean seed treatments according to the application technology: continuous flow IST, batch IST, OnFarm and untreated control (white).

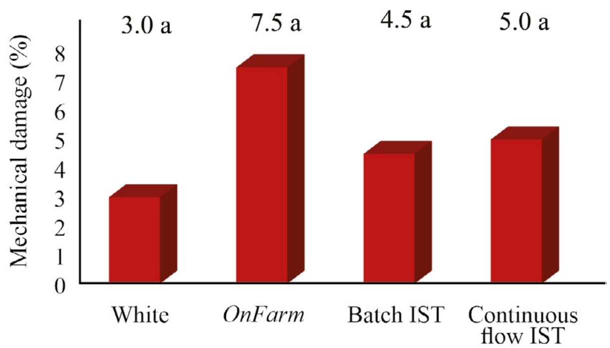

Figure 2: Mean percentage of mechanical damage occurrence determined by the sodium hypochlorite test in soybean seeds treated in different systems and the control. *Means followed by the same letter do not differ by Tukey's test at 5%.

Soybeans have characteristics that favor the occurrence of mechanical damage, since the vital parts of the embryonic axis, such as the radicle, hypocotyl and plumule, are located under a thin integument, which offers practically no protection (Marcos Filho, 2015). Thus, care must be taken in soybean treatment, and machinery must be selected that reduces the occurrence of mechanical damage.

The low occurrence of mechanical damage in soybean seed lots is important because mechanical damage directly affects the physiological quality of the seeds (Moreano et al., 2018; Oliveira et al., 2021).

Another relevant characteristic determining the functional quality of treatment is the coating of the seeds by chemical products, which is a fundamental property according to producers and the market. For the most part, coating effectiveness is evaluated only visually, which produces highly unreliable and imprecise results. Through digital processing of high-resolution images, it was possible to measure the seed coating for each treatment. The percentage coating of the treated seeds was calculated as the sum of the percentages of Color: Red Dominance and Color: Pink Dominance, according to the predominance of red and pink colors of the products used in the treatment.

The industrial seed technology, either by batch or continuous flow, provided better seed coating; in both cases, the percent coating was above 99%, higher than that (88%) obtained in the *OnFarm* treatment system (Figure 3). This reiterates the importance of application technology in correctly distributing and coating the product. IST handler technologies promote the efficiency of product dose application, the uniformity of coverage and the adherence of the products to the seeds (Decarli et al., 2019). In contrast, seeds treated in the *OnFarm* system, with application via fixed-volume doser and mixing via worm screw, which are simpler technologies than those used in IST, the coating percentage was lower, resulting in less uniform seed coverage and possibly implying lower dose effectiveness of the seeds.

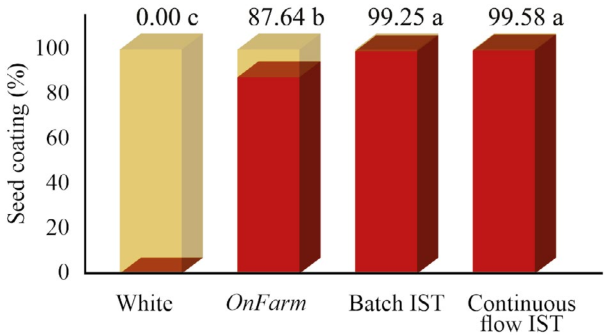

Figure 3: Mean percentage of soybean seed coating by phytosanitary products as a function. *Means followed by the same letter do not differ by Tukey's test at 5%.

The accuracy of dose application is a relevant factor because it can directly affect the action and efficiency of the products, as well as the costs of products and seeds and the significance of the treatment for soybean cultivation. Figure 4 shows the HPLC quantification of the active ingredient thiamethoxam, an insecticide present in all treatments (except in the control seeds, without treatment); the values are converted to percentages as a function of the desired dose of 0.7 g thiamethoxam kg^{-1} seeds (100%). The *OnFarm* treatment resulted in lower dose effectiveness, with only 81% (0.57 g^{-1} kg) of the desirable concentration of the active ingredient thiamethoxam. Conversely, the IST treatments produced an effectiveness above 95% (0.67 g^{-1} kg), with no difference between treatments.

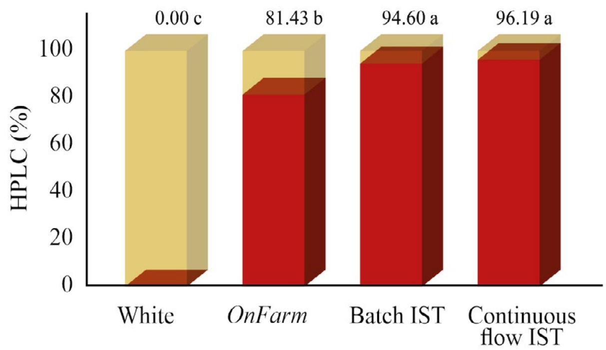

Figure 4: Mean percentage relative to the desirable dose (100%) of the active ingredient thiamethoxam, quantified by HPLC in soybean seeds treated in different handlers and the control. *Means followed by the same letter do not differ by Tukey's test at 5%.

IST ensures better efficiency in the application and distribution of products and therefore uniformity of seed coverage (França-Neto et al., 2015).

The dose effectiveness of the active ingredient, determined by HPLC (Figure 4), corroborates the percentage seed coating results for the STs (Figure 3), indicating that better seed coating is directly related to a better dose distribution on the seeds.

The lower release of particles after seed treatment is desirable because it is related to lower product loss and greater environmental safety in agricultural operations (Nuyttens et al., 2013). Seeds treated with industrial technology exhibited less dust release, showing the efficiency of this treatment method in adhering the products to the seeds. Untreated seeds generated more dust than those treated with IST, even without chemical particles in their composition; this dust production is related to common adhered organic residues and dust on soybean seeds. Seeds treated with *OnFarm* technology exhibited greater particle detachment than the other treatments (Figure 5), with values above the maximum limit recommended in Europe for the detachment of particles/dust from treated soybean seeds, which is 4 g dust 100 kg^{-1} seeds, according to the (European Association for Quality Assurance in Seed Treatment – ESTA, 2022).

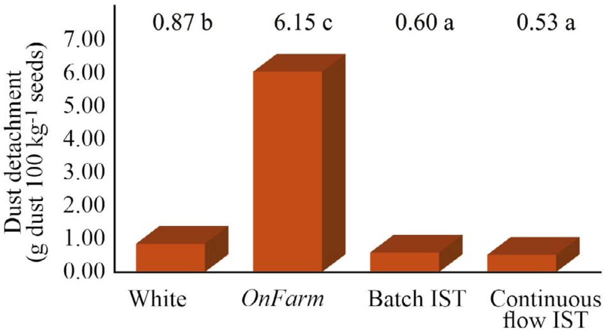

Figure 5: Mean dust detachment (g dust 100 kg^{-1} seeds) of soybean seeds treated with phytosanitary products according to treatment. *Means followed by the same letter do not differ by Tukey's test at 5%.

Although the products used were the same in both IST and *OnFarm*, including the polymer, the application and distribution technologies affected the adhesion of the product to the seeds and consequent detachment of particles. The simpler technology used in *OnFarm* equipment caused less adhesion of the products to the seeds and thus greater formation of dust. The formation of dust in treated seeds is directly related to the adhesion of the products, possibly indicating incompatibility between formulations, loss of the active ingredients after treatment, and consequently inefficient protection (Avelar et al., 2012).

The lower generation of dust by IST reduces the environmental and human health impacts from toxic dust and ensures seed protection, in addition to minimizing the exposure of humans and natural predators to phytosanitary products during sowing (Nuyttens et al., 2013).

CONCLUSIONS

The treatment of soybean seeds in either batch or continuous flow industrial handlers ensures better seed coating, greater dose effectiveness, less particle detachment and a lower occurrence of mechanical damage compared to *OnFarm* application technology. The digital processing of high-resolution images is efficient for quantifying the coating of soybean seeds by phytosanitary products. Seed coating is directly related to dose effectiveness.

AUTHOR CONTRIBUTION

Conceptual Idea: Oliveira Junior, A.; Carvalho, E.R.; Methodology design: Reis, L.V.; Reis, V.U.V.; Nardelli, A.C.P.; Data collection: Reis, L.V.; Reis, V.U.V.; Andrade, D.B.; Oliveira Junior, A.; Data analysis and interpretation: Reis, L.V.; Reis, V.U.V.; Andrade, D.B., and Writing and editing: Reis, L.V.; Nardelli, A.C.P.; Carvalho, E.R.

ACKNOWLEDGMENTS

The authors thank the National Council for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq), the Minas Gerais Research Foundation (Fundação de Amparo à Pesquisa do Estado de Minas Gerais - FAPEMIG) and the Coordination for the Improvement of Higher Education Personnel (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES) for the financial support, scholarships and research productivity scholarship and the Seedcare Institute for the support and partnership.

REFERENCES

AVELAR, S. A. G. et al. The use of film coating on the performance of treated corn seed. Revista Brasileira de Sementes, 34(2):186-192, 2012.

BRZEZINSKI, C. R. et al. Seeds treatment times in the establishment and yield performance of soybean crops. Journal of Seed Science, 37(2):147-153, 2015.

CARVALHO, E. R. et al. Phytotoxicity in soybean seeds treated with phytosanitary products at different application times. Journal of Seed Science, 42:e202042036, 2020.

CARVALHO, E. R. et al. Soil water restriction and performance of soybean seeds treated with phytosanitary products. Revista Brasileira de Engenharia Agrícola e Ambiental, 26(1):59-66, 2022.

DECARLI, L. et al. Tratamento industrial em sementes de soja: Qualidade fisiológica e desempenho da cultura. Revista Brasileira de Ciências Agrárias, 14(3):e6235, 2019.

EUROPEAN SEED TREATMENT ASSURANCE - ESTA. Dust reference values heubach test method. 2022. Available in: <https://euroseeds.eu/esta-the-european-seed-treatment-assurance-industry-scheme/dust-reference-values-heubach-test-method/>. Access in: March 2, 2023.

FERREIRA, D. F. Sisvar: A computer analysis system to fixed effects split plot type designs. Brazilian Journal of Biometrics, 37(4):529-535, 2019.

FERREIRA, T. F. et al. Quality of soybean seeds treated with fungicides and insecticides before and after storage. Journal of Seed Science, 38(4):278-286, 2016.

FRANÇA-NETO, J. B. de. et al. Adoção do tratamento industrial de sementes de soja no Brasil, safra 2014/2015. Informativo ABRATES, 25(1):26-29, 2015.

KRZYZANOWSKI, F. C.; FRANÇA NETO, J. B. F.; COSTA, N. P. Teste do hipoclorito de sódio para semente de soja. Londrina, Paraná, Brasil: EMBRAPA-CNPF, 2004. 4p. (Circular Técnica 37)

LUDWIG, M. P. et al. Eficiência do recobrimento de sementes de soja em equipamento com sistema de aspersão. Ciência Rural, 41(4):557-563, 2011.

MARCOS FILHO, J. Fisiologia de sementes de plantas cultivadas. 2ª ed. Londrina, Paraná, Brasil: ABRATES, 2015. 660p.

MOREANO, T. B. et al. Evolution of the physical and physiological quality of soybean seeds during processing. Journal of Seed Science, 40(3):313-322, 2018.

NUNES, J. C. S. Tratamento de sementes de soja como um processo industrial no Brasil. Seed News, 2016. Available in: <https://seednews.com.br/artigos/334-tratamento-de-sementes-de-soja-como-um-processo-industrial-no-brasil-edicao-janeiro-2016>. Access in: March 3, 2023.

NUYTTENS, D. et al. Pesticide-laden dust emission and drift from treated seeds during seed drilling: A review. Pest Management Science, 69(5):564-575, 2013.

OLIVEIRA, G. R. F. et al. Treatment of soybean seeds with mechanical damage: Effects on their physiological potential. Journal of Seed Science, 43:e202143023, 2021.

PLATZEN, H. Tratadoras de sementes. Seed News, 2010. Available in: <https://seednews.com.br/artigos/1883-tratadoras-de-sementes-edicao-novembro-2010>. Access in: March 3, 2023.

SANTOS, S. F. et al. Composition and volumes of slurry in soybean seeds treatment in the industry and physiological quality during storage. Journal of Seed Science, 40(1):67-74, 2018.