

Physiological potential of soybean seeds treated in the industry with and without the application of dry powder¹

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ABSTRACT - In soybean crops, industrial seed treatment is widely adopted, and it has allowed the development of new technologies, such as the use of dry powders. This work aimed to evaluate the effect of the industrial treatment, with and without the additional application of dry powder, on the physiological potential of soybean seeds. The experimental design was completely randomized, in a 4×2 factorial scheme, with four replications. Four chemical treatments were evaluated: 1) control, 2) carbendazim + thiram + thiamethoxam, 3) carbendazim + thiram, 4) thiamethoxam. Each trial was divided into one group that was treated and the other that remained untreated with the dry powder. The cultivars BRS 360 RR and BRS 284 were used and analyzed separately. The physiological potential of the seeds was determined by the following assessments: germination, first germination count, seedling emergence in sand, seedling total length, shoot length, and root length. Soybean cultivars respond differently to seed chemical treatments, regarding the effects on physiological potential. Using the dry powder results in problems in seed germination speed in the cultivar BRS 284. In the cultivar BRS 360 RR, the use of dry powder associated with thiamethoxam treatment reduces the physiological potential of the seeds.

Index terms: *Glycine max* (L.) Merrill., fungicides, insecticides, germination, emergence of seedlings.

Potencial fisiológico de sementes de soja tratadas industrialmente com e sem a aplicação de pó secante

RESUMO - Na cultura da soja, o tratamento industrial de sementes é amplamente realizado e tem propiciado o desenvolvimento de novas tecnologias, como a utilização de pó secante. O objetivo deste trabalho foi avaliar o efeito do tratamento industrial de sementes, com e sem a aplicação de pó secante, sobre o potencial fisiológico de sementes de soja. O delineamento experimental foi inteiramente casualizado, em esquema fatorial 4x2, com quatro repetições, sendo avaliados quatro tratamentos químicos de sementes: 1) testemunha, 2) carbendazim + thiram + tiametoxam, 3) carbendazim + thiram, 4) tiametoxam; todos na ausência e na presença de pó secante. As cultivares utilizadas foram a BRS 360 RR e a BRS 284, que foram analisadas separadamente. O potencial fisiológico das sementes foi determinado por meio das seguintes avaliações: germinação, primeira contagem de germinação, emergência de plântulas em areia, e comprimentos total, da parte aérea e da raiz das plântulas. As cultivares de soja respondem de forma diferenciada aos tratamentos químicos de sementes, quanto aos efeitos no potencial fisiológico. O pó secante resulta em problemas na velocidade de germinação das sementes da cultivar BRS 284. Na cultivar BRS 360 RR, o uso de pó secante associado ao tratamento com tiametoxam reduz o potencial fisiológico das sementes.

Termos para indexação: *Glycine max* (L.) Merrill., fungicidas, inseticidas, germinação, emergência de plântulas.

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Introduction

Soybean is a prominent culture in Brazil and worldwide. Within the agrobusiness scope, it is one of the economic activities that has increased the most in the last decades. This can be attributed to several factors, such as the development of technologies that boosted productivity, and also made the cultivation in different regions possible (Sediyama et al., 2013; Hirakuri and Lazzarotto, 2014).

Among these technologies, seed treatment stands out as an important way of controlling pathogens transmitted by seeds, and of ensuring the establishment of adequate plant populations. This is particularly relevant when the edaphoclimatic conditions during sowing are not favorable to germination and emergence of seedlings (Mertz et al., 2009; Balardin et al., 2011; Pereira et al., 2011).

Traditionally, seed treatment used to be performed before sowing, with proper machines, either at the resale or at the farmer's property. However, seed companies, especially those who deal with soybean and corn seeds, have been adopting the seed treatment in the industry (STI), in which seeds are treated on the processing line, before storage, or at the moment of delivery. This form of treatment associates equipment and techniques of great efficiency and precision, and it allows the use of new chemicals and formulations. Furthermore, it provides a greater protection to the operators, and reduces the contamination of the environment (França-Neto et al., 2015).

The treatment of soybean seeds in the industry showed physiological and sanitary advantages (Ludwig et al., 2011; Brzezinski et al., 2015; Conceição et al., 2016; Ferreira et al., 2016). However, problems were also reported, mainly in lots of low vigor seeds that had been submitted to excessively high volumes of slurry, resulted from the use of technological packs provided by the companies (Brzezinski et al., 2017). To solve this problem, companies have used dry powder in order to induce seeds to dry fast and evenly. Thus, it is necessary to study the effects of the dry powder and its interaction with the chemical treatments on the physiological quality of the seeds.

On account of that, the objective of the present work was to assess the effect of the seed treatment in the industry, with and without the application of dry powder, on the physiological potential of soybean seeds.

Material and Methods

The experiment was conducted in the Laboratory of Physiology and Technology of Seeds, at the Technological Center of Seeds and Grains of *Empresa Brasileira de Pesquisa Agropecuária, Embrapa Soja*, located in the city of Londrina, state

of Paraná (PR). The cultivars BRS 360 RR and BRS 284 were used, and they presented similar physiological quality prior to the treatments, with germination values of 96% and 93%, respectively, and moisture content of 11.5%, in both cultivars.

The experimental design was completely randomized, in a 4x2 factorial scheme, with four replications. The factors were composed by four seed chemical treatments: T1) control (no chemical treatment); T2) fungicide carbendazim + thiram (Derosal Plus®) + insecticide thiamethoxam (Cruiser®), dose 200 + 200 mL. 100 kg⁻¹ seeds; T3) carbendazim + thiram (Derosal Plus®), dose 200 mL. 100 kg⁻¹ seeds; T4) thiamethoxam (Cruiser®), dose 200 mL. 100 kg⁻¹ seeds. All trials were performed with and without the application of the dry powder (dose 200 g. 100 kg⁻¹ seeds).

The seeds were treated (1 kg per treatment) in a BMC (Batch Modular Coater) machine, similar to those used in industrial treatment (STI), but designed for small quantities. The seeds were put inside the machine, and then the chemicals (fungicides and insecticides), and for last, the dry powder were added.

Right after the industrial treatment, the physiological potential of the seeds was determined through the following evaluations:

Germination: it was performed with two subsamples of 50 seeds per replication, in a total of 400 seeds per treatment. The seeds were distributed on germitest paper rolls, moistened with distilled water in the proportion of 2.5 times the substrate dry mass. Next, the paper rolls were placed inside germinator at 25 °C for 8 days. After that period, the normal seedlings were counted, and the result was expressed as percentage (Brasil, 2009).

First germination count: it was carried out jointly with the germination test. The evaluation was done five days after the test setup, when the normal seedlings were counted. The result was expressed as percentage (Brasil, 2009).

Seedling emergence in sand: it was conducted with 400 seeds per treatment, divided into four replications of 100 seeds. Sowing was performed in plastic trays (0.45 x 0.30 x 0.10 m dimensions) containing sand, in which the seeds were planted to a depth of 3 cm. The test was carried out under oven conditions, and the moisture was maintained through irrigation, according to the seedlings' needs. The final count of emerged normal seedlings was done on the twelfth day, and the results were expressed as percentage.

Seedling total length, shoot length and root length: five subsamples of 20 seeds each were used, totalizing 100 seeds per treatment. The seeds were distributed on germination paper rolls, moistened with distilled water in the proportion of 2.5 times the dry paper mass. Then, they were kept in germinator at 25 °C for five days (Nakagawa, 1999).

Subsequently, the lengths of the seedlings (total), shoots and roots were measured with a millimeter ruler, and the results were expressed in centimeter per seedling.

The resulting data were analyzed as for normality and homoscedasticity by the Shapiro-Wilk and Hartley tests, respectively. Also, the analysis of variance was performed, and the means were compared by the Tukey's test at a probability of 5%. The cultivars were assessed separately. The statistical analyzes were carried out with the computer software *Sistema para Análise de Variância – SISVAR* (Ferreira, 2014).

Results and Discussion

In the cultivar BRS 360 RR, the analysis of variance showed a significant interaction between the factors studied (seed chemical treatments and dry powder) in the variables germination, first germination count, seedling total length, shoot length, and root length. In the cultivar BRS 284, the interaction was significant in the variables seedling total length, shoot length, and root length. Additionally, it was

possible to notice the independent effect of the seed chemical treatments on seedling emergence, in the cultivar BRS 360 RR, and the independent effect of the dry powder on the first germination count, in the cultivar BRS 284.

The outcome of the first germination count in the cultivar BRS 360 RR showed that seeds treated with thiamethoxam (T4) and dry powder presented a lower germination speed, in comparison with those untreated with the dry powder (Table 1). Also, seed treatment with thiamethoxam (T4) caused a reduction in the first germination count, compared to the control (T1) and the treatment with carbendazim + thiram + thiamethoxam (T2), when the dry powder was used (Table 1). On the other hand, Tavares et al. (2007) did not observe differences in germination nor vigor of soybean seeds treated with different doses of thiamethoxam. Similarly, Barros et al. (2001) and Dan et al. (2011), in their works with beans and soybeans, respectively, verified that the germination of seeds treated with thiamethoxam did not differ in relation to the control treatment.

Still considering the variable first germination count, the results from the cultivar BRS 284 showed that the use

Table 1. Germination (G), first germination count (FC), seedling total length (STL), shoot length (SL), root length (RL) of soybean seeds from the cultivars BRS 360 RR and BRS 284 submitted to different chemical treatments, with and without the application of dry powder.

----- BRS 360 RR -----							
VF	G (%)		FC (%)		STL (cm)		
Treatments ¹	With	Without	With	Without	With	Without	
T1	97 Aa	96 Aa	96 Aa	95 Aa	29.70 Ba	29.27 Aa	
T2	96 Aa	95 Aa	96 Aa	93 Aa	34.00 Aa	26.70 Bb	
T3	96 Aa	96 Aa	93 ABa	95 Aa	32.47 Aa	24.00 Cb	
T4	93 Ab	98 Aa	91 Bb	98 Aa	24.82 Cb	28.80 ABa	
CV (%)	2.29		2.97		3.90		
VF	SL (cm)		RL (cm)				
Treatments ¹	With	Without	With	Without	With	Without	
T1	11.40 Ba	10.57 Aa	18.30 BCa	18.65 Aa			
T2	13.77 Aa	9.37 Bb	20.20 Aa	17.32 ABb			
T3	13.27 Aa	7.47 Cb	19.22 ABa	16.52 Bb			
T4	7.95 Cb	11.40 Aa	16.87 Ca	17.40 ABa			
CV (%)	5.62				4.66		
----- BRS 284 RR -----							
VF	STL (cm)		SL (cm)		RL (cm)		
Treatments ¹	With	Without	With	Without	With	Without	
T1	28.40 ABa	28.75 Aa	9.75 Aa	9.60 Aa	18.70 Aa	19.17 Aa	
T2	27.12 Ba	26.05 ABa	7.90 Ba	7.72 Ba	19.30 Aa	18.30 Aa	
T3	20.00 Cb	23.57 Ba	7.20 Bb	8.35 ABa	12.82 Bb	15.22 Ba	
T4	30.62 Aa	18.30 Cb	9.50 Aa	5.07 Cb	21.12 Aa	13.22 Bb	
CV (%)	6.96		9.12		7.98		

Means followed by the same lowercase letter in the row, and uppercase letter in the column do not differ from each other, according to the Tukey's test at a probability of 5%.

¹Treatments: 1 – control (no chemical treatment); 2 – carbendazim + thiram + thiamethoxam; 3 – carbendazim + thiram; and 4 – thiamethoxam.

of the dry powder reduced the germination speed in all treatments (Table 2). The dry powder has in its composition mica coated with titanium dioxide and natural talc-chloride, which, according to Clifton (1985), is a substance of hydrophilic nature. Therefore, applying dry powder over the seeds provides a fast drying of liquids, as result of a natural physical process. However, such absorption may cause water withdrawal from the seeds and damages related to imbibition. According to Toledo et al. (2010), these damages lead to problems in soybean seed germination, because they interfere in organelle structure, especially cell membranes. When the imbibition occurs fast, the cell membranes do not provide an efficient barrier against the release of solutes.

For the variable germination, the results of the cultivar BRS 360 RR were similar to those observed in the first germination count, in which the application of the dry powder in the treatment with thiamethoxam (T4) reduced the percentage of germination, in comparison with the equivalent treatment without the dry powder (Table 1). Possibly, this has to do with a phytotoxic effect of these products when used combined, which compromised seed germination. As stated by França-Neto et al. (2016), the phytotoxic effect provokes atrophy of the root system, and also causes the epicotyl to get thicker, shorter, stiffer, and to present longitudinal fissures. These characteristics negatively affect the physiological quality of the seeds, as shown by the present study. Still, all germination values were above 80%, the minimum required by the Ministry of Agriculture for commercialization of soybean seeds in Brazil (MAPA, 2013).

For seedling emergence in sand, the seeds of cultivar BRS 360 RR treated with carbendazim + thiram + thiamethoxam (T2) and thiamethoxam (T4) showed a higher percentage of emergence when compared to the untreated ones (T1) (Table 3). This behavior is distinct from the all the other variables, and the difference is possibly related to the substrate: while sand was used in the emergence test, paper was used to assess the other variables. In the seedling emergence test, the contact between the chemicals on seed tegument and the developing structures of the seedling is minimized. This occurs both due to the leaching of the product in the sandy substrate, and also because of the release of the tegument in the substrate, so it does not keep direct contact with the seedling during germination, which reduces the phytotoxic effect of the products.

As for the seedling growth, there was an interaction between the chemical treatments and the use of dry powder in both cultivars. In BRS 360 RR, the outcome was similar for the variables seedling total length and shoot length. In these cases, using dry powder favored seedling total growth

and shoot growth in seeds treated with carbendazim + thiram + thiamethoxam (T2) and carbendazim + thiram (T3). However, it was harmful when associated with thiamethoxam (T4), compared to seeds untreated with the dry powder (Table 1). Also, it was possible to verify that the insecticide thiamethoxam (T4) reduced the seedling total length and the shoot length, in comparison with the other treatments that used the dry powder. Without it, the seeds treated with carbendazim + thiram (T3) presented the lowest values for the variables mentioned.

In the cultivar BRS 284, the application of the dry powder reduced seedling total length in the treatment with carbendazim + thiram (T3). On the other hand, it favored seedling growth in the treatment with thiamethoxam (T4). A comparison among the seed treatments allowed to notice that the products carbendazim + thiram (T3) and thiamethoxam (T4), respectively with and without the dry powder treatment, caused reduction in the length of the seedlings (Table 1).

Regarding the shoot length of the seedlings, in the cultivar BRS 284, the use of the dry powder in association with thiamethoxam (T4) resulted in a greater shoot growth, in relation to the equivalent treatment without the dry powder. Meanwhile, between the treatments with carbendazim + thiram (T3), the greatest values were observed in the one without the dry powder. Also, when associated with the dry

Table 2. First germination count (FC) of soybean seeds from the cultivar BRS 284, with and without the application of the dry powder.

Dry powder	FC (%)
With	89 B
Without	92 A
CV (%)	4.53

Means followed by the same letter do not differ from each other, according to the Tukey's test at a probability of 5%.

Table 3. Seedling emergence in sand (ES) of soybean seeds from the cultivar BRS 360 RR submitted to different chemical treatments.

Treatments ¹	ES (%)
T1	96 B
T2	98 A
T3	97 AB
T4	99 A
CV (%)	1.35

Means followed by the same letter do not differ from each other, according to the Tukey's test at a probability of 5%.

¹Treatments: 1 – control (no chemical treatment); 2 – carbendazim + thiram + thiamethoxam; 3 – carbendazim + thiram; and 4 – thiamethoxam.

powder, both carbendazim + thiram + thiamethoxam (T2) and carbendazim + thiram (T3) treatments reduced the shoot length. When the dry powder was not applied, the seeds treated with thiamethoxam (T4) showed seedlings with less shoot growth, in relation to the other treatments (Table 1).

Almeida et al. (2012) and Santos et al. (2014), in their respective studies on black oat seeds sowed in paper substrate, and soybean seeds planted in sand, verified that the treatment with thiamethoxam presented a phytotonic effect, which is characterized by a greater growth and development of the seedlings. According to Castro et al. (2008), the insecticide thiamethoxam acts on the expression of genes responsible for the synthesis and activation of enzymes related to plant growth. Consequently, it alters the production of amino acids precursors of plants hormones that positively affect germination and vigor. Nevertheless, such effects were not observed in this work, since the results from the treatment with thiamethoxam (T4) were not superior to those of seeds untreated with this chemical. In the cultivar BRS 360 RR, the insecticide thiamethoxam (T4), whether with or without the dry powder, even damaged the physiological quality of the seeds in all variables assessed, except for the emergence in sand (Table 1).

As for the root length, seeds of the cultivar BRS 360 RR treated with carbendazim + thiram + thiamethoxam (T2) and carbendazim + thiram (T3), both added of dry powder, presented greater length in relation to the seeds untreated with the powder (Table 1). When the dry powder was used, the treatment with thiamethoxam (T4) provided lower values for the same variable, in comparison with the treatments with carbendazim + thiram + thiamethoxam (T2) and carbendazim + thiram (T3). In the seeds untreated with the dry powder, the use of carbendazim + thiram (T3) produced seedlings with smaller root length, in relation to the control treatment (T1) (Table 1).

In the cultivar BRS 284, the treatment with carbendazim + thiram (T3) and dry powder resulted in less root growth. Also, in seeds untreated with the dry powder, the treatments with carbendazim + thiram (T3) and with thiamethoxam (T4) generated the lowest values for this variable. Considering the use of dry powder within the same treatment, it was noticeable that the combination of carbendazim + thiram (T3) and dry powder reduced the root length, in relation to the seeds untreated with dry powder. In their turn, the combined use of thiamethoxam (T4) and dry powder on seeds produced the highest values of this variable (Table 1).

The cultivars exhibited different responses to the seed chemical treatments and to the use of dry powder. It probably occurred because the cultivars have distinct characteristics regarding tegument permeability, chemical composition, and other factors. Together, they might have contributed to the

differences observed among the treatments.

Conclusions

The soybean cultivars showed different responses to the seed chemical treatments regarding the effects on the physiological potential.

The dry powder reduces the germination speed of seeds from the cultivar BRS 284.

In the cultivar BRS 360 RR, the treatment with thiamethoxam associated with the dry powder reduces the physiological potential of the seeds.

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