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Spray volumes in the industrial treatment on the physiological quality of soybean seeds with different levels of vigor[1]

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ABSTRACT - The aim of this work was to evaluate the effect of different spray volumes, via industrial treatment, on the physiological quality of soybean seeds with different levels of vigor. The experimental design was completely randomized in a 2x5 factor scheme, with four replications. Factors consisted in two levels of seed vigor (high and low) and five spray volumes (0, 600, 1200, 1800 and 2400 mL. 100 kg^{-1}). Products used to obtain the volumes were: fungicide (carbendazin + thiram); insecticide (imidacloprid + thiodicarb); nematicide (abamectin); micronutrients (cobalt, molybdenum and zinc); polymer (peridiam); biostimulants (kinetin + gibberellic acid) and inoculum (*Bradyrhizobium japonicum*). The used cultivars were BRS 360 RR and BRS 1010 IPRO. The physiological seed quality was determined by the following evaluations: germination, first count of the germination test, seedling emergence in sand, emergency speed index, total length of shoot and root of the seedlings. In the different spray volumes, high vigor soybean seeds have higher physiological quality than low vigor seeds. The increased spray volumes in seed treatments reduce the physiological quality of low vigor soybean seeds.

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

Volumes de calda no tratamento industrial sobre a qualidade fisiológica de sementes de soja com diferentes níveis de vigor

RESUMO - O objetivo foi avaliar o efeito de diferentes volumes de calda, via tratamento industrial, sobre a qualidade fisiológica de sementes de soja com diferentes níveis de vigor. O delineamento experimental foi inteiramente casualizado, em esquema fatorial 2x5, com quatro repetições. Os fatores foram constituídos por sementes com dois níveis de vigor (alto e baixo) e cinco volumes de calda (0, 600, 1200, 1800 e 2400 mL. 100kg^{-1}). Os produtos utilizados para a obtenção dos volumes foram: fungicida (carbendazin + thiram); inseticida (imidacloprido + tiodicarbe); nematicida (abamectina); micronutriente (cobalto, molibdênio e zinco); polímero (peridiam); bioestimulante (cinetina + ácido giberélico) e inoculante (*Bradyrhizobium japonicum*). As cultivares utilizadas foram BRS 360 RR e BRS 1010 IPRO. A qualidade fisiológica das sementes foi determinada pelas seguintes avaliações: germinação, primeira contagem do teste de germinação, emergência de plântulas em areia, índice de velocidade de emergência, comprimento total, de parte aérea e raiz de plântulas. Nos diferentes volumes de calda, as sementes de soja de alto vigor apresentam maior qualidade fisiológica em relação às sementes de baixo vigor. O aumento do volume de calda no tratamento de sementes reduz a qualidade fisiológica das sementes de soja de baixo vigor.

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

Introduction

Soybean [*Glycine max* (L.) Merrill] stands out as the main oleaginous plant cultivated and consumed in the world, due to its use for human and animal diet and the production of biofuel (Hirakuri and Lazzarotto, 2014). However, productivity increases are still necessary and possible, through practices such the use of high quality seeds (Mertz et al., 2009; Moterle et al., 2011).

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High quality seeds must present proper sanitary, physical, genetic and physiological characteristics, such as high germination and vigor rates (Zorato and Henning, 2001; França-Neto et al., 2010; Marcos-Filho, 2015). Within the physiological attributes, seed vigor plays a relevant role in the agricultural production, since more vigorous seeds provide quick and even germination, helping the growth of the shoot and the root system, providing plants better development conditions (Bennett, 2001; Carvalho and Nakagawa, 2012).

Improper edaphoclimatic conditions may affect germination and seedling emergence and they may also damage the initial development of the culture. Thus, treating soybean seeds becomes an essential practice to assure the proper stand, by controlling diseases during the initial period of the cultivation, as well as reducing the possibility of penetrating pathogens in intact areas (Balardin et al., 2011; Pereira et al., 2011).

The chemical seed treatment was commonly performed during pre-sowing, both in the farmer's property and the resale itself, with the help of specific machines. However, with the technological advance of agriculture, seed producing companies have been adopting techniques that may maximize the culture yield, such as the industrial seed treatment process (IST), where seeds are treated in the processing line itself and, after that, they are bagged and stored until sowing. This treatment strategy, associated with the use of more effective and precise equipments and techniques, as well as enabling the use of new formulas, containing fungicides, insecticides, nematicides, polymers, micronutrients, biostimulants and inoculum in the same treatment (Brzezinski et al., 2015).

The association of various products in the industrial treatment may result in higher spray volumes than the ones used in the traditional treatment. Thus, exploring studies indicate the possibility of using higher spray volumes without the occurrence of negative effects on the physiological performance of seeds (Krzyzanowski et al., 2007). Segalin et al. (2013) verified that treating soybean seeds with spray volumes up to 1400 mL. kg^{-1} did not cause reductions in the physiological quality.

Associated to this, the use of seeds with different vigor levels may also influence the spray volume quantity to be used. According to Carvalho and Nakagawa (2012), the response to a treatment with fungicide depends on the seed vigor. Higher vigor seeds present favorable responses to chemical treatments, whereas medium vigor seeds respond up to a certain extent and the ones with lower vigor practically do not respond. Gomes et al. (2009) verified that lower vigor soybean seeds treated with the fungicide fludioxonil presented less response in relation to higher vigor seeds.

The use of greater spray volumes in the IST, with no consequences for the physiological performance, depends on various factors, among which there is seed vigor. Thus, the goal of this work was to evaluate the effect of different spray volumes, via industrial treatment, over the physiological quality of soybean seeds with different vigor levels.

Material and Methods

The test was conducted at Embrapa in Núcleo Tecnológico de Sementes e Grãos of the Empresa Brasileira de Pesquisa Agropecuária, in Londrina, Paraná state, at the Laboratórios de Fisiologia e Tecnologia de Sementes. The cultivars BRS 360 RR and BRS 1010 IPRO were used; they were analyzed separately.

The experimental design was completely randomized, in a 2x5 factor scheme, with four replications. Factors consisted in seeds with two vigor levels (high and low) and five spray volumes (0, 600, 1200, 1800 and 2400 mL. $100kg^{-1}$).

Seeds that were classified as low vigor ones were obtained from high vigor seed lots, through the application of the accelerated aging technique. In order to conduct the aging, seeds were placed in gerbox® type crystal polystyrene boxes, with canvas supports, containing 40 mL of distillated water. After that, they were placed in a Water-jacketed incubation chamber, at the temperature of 41 °C for 48 hours, thus causing reduction in their vigor. Seeds that were not submitted to accelerated aging were considered high vigor ones and aged seeds were considered low vigor ones.

In order to characterize the seed lots according to the vigor, the physiological quality of seeds was determined by the following tests (Table 1): *Germination and germination first count* - performed according to the Rules for Seed Testing (Brasil, 2009); *Total length of seedling shoot and roots* - according to the methodology proposed by Nakagawa (1999); *Dry matter mass of shoot and roots* - performed according to Nakagawa (1999); Seedling emergence speed index - conducted under greenhouse conditions, using the equation suggested by Maguire (1962); *Seedling emergence in sand* - referring to the total count of seedlings emerged 12 days after sowing.

In order to obtain different spray volumes, the maximum volume to be used was initially determined and, starting from it, the other volumes were obtained by decreasing doses of inoculum, biostimulants, polymers and micronutrients (Table 2). The used products were: F: fungicide carbendazim + thiram (Derosal Plus®); I: insecticide imidacloprid + tiodicarbe (Cropstar®); N: nematicide amabectin (Abamectin®); M: micronutrients cobalt, molybdenum and zinc (Broadacre CMZ®); P: polymer (Peridiam®); B: biostimulant kinetin + gibberellic acid, such as GA3 + 4-indole-3-butryc acid (Stimulate®) and IN: Inoculum *Bradyrhizobium japonicum* (Gelfix 5®).

Table 1. Average values of physiological quality attributes of soybean seeds, in order to characterize lots with high vigor (HV) and low vigor (LV).

Cultivar	FCG		G		TSL		LAP		RL	
	HV	LV	HV	LV	HV	LV	HV	LV	HV	LV
BRS 360 RR	93	85	96	92	25.08	19.52	9.50	8.69	15.58	10.83
BRS 1010 IPRO	89	78	93	86	24.35	18.70	8.50	7.33	15.85	11.37

Cultivar	DMAP		RDM		ESI		SE	
	HV	LV	HV	LV	HV	LV	HV	LV
BRS 360 RR	1.78	1.61	0.73	0.48	25.74	19.03	98	86
BRS 1010 IPRO	1.59	1.24	0.89	0.59	24.22	18.87	97	86

FCG: First count of germination (%); G: Germination (%); TSL: Total seedling length (cm); LAP: Shoot length (cm), RL: Root length (cm); DMAP: Dry matter of the shoot (mg per seedling); RDM: Root dry matter (mg per seedling); ESI: Emergence speed index and SE: Seedling emergence in sand (%).

Table 2. Products and doses used in the industrial treatment of soybean seeds to obtain different spray volumes (mL. $100kg^{-1}$).

Volumes	F[1]	I	N	M	P	B	IN	Total
0 (control sample)	-	-	-	-	-	-	-	0
600	200[2]	300	100	-	-	-	-	600
1200	200	300	100	400	200	-	-	1200
1800	200	300	100	400	200	600	-	1800
2400	200	300	100	400	200	800	400	2400

[1]Product type: F: fungicide (carbendazim + thiram); I: insecticide (imidacloprid + tiodicarbe); N: nematicide (amabectin); M: micronutrients (cobalt, molybdenum and zinc); P: polymer (peridiam); B: biostimulant (kinetin + gibberellic acid, such as GA3 + 4-indole-3-butryc acid) and IN: Inoculum (*Bradyrhizobium japonicum*).
[2]Commercial product dose: mL. $100kg^{-1}$ of seeds.

Seed treatment was performed using a Batch Modular Coater (BMC) machine, which simulates the industrial treatment of seeds in lower quantities.

In order to determine the physiological the following evaluations were performed:

Germination: performed with four subsamples of 50 seeds per replication, totalizing 800 seeds per treatment. Seeds were positioned on paper towel rolls and moistened in the proportion of 2.5 times the dry paper mass in water. After this, rolls were taken to a germinator at the temperature of 25 °C. Evaluations were performed 8 days after seeding, according to the Rules for Seed Testing (Brasil, 2009), counting the normal seedlings, and the results were expressed in percentage.

First count of the germination test: performed together with the germination test. The evaluation was performed five days after seeding, counting only the normal seedlings, with results expressed in percentage (Brasil, 2009).

Seedling emergence in sand: performed with 800 seeds per treatment, divided into two subsamples of 100 seeds per each replication. Sowing was made in plastic trays containing sand. The test was conducted under greenhouse conditions (Van der Hoeven® model) and the substrate moisture was maintained with irrigations, according to the seedlings' need. The final evaluation on the number of normal emerged seedlings was performed in the twelfth day, and the results were expressed in percentage.

Seedling emergence speed index: performed together with the seedling emergence test in sand. Evaluations were performed daily, starting from the beginning of emergence, recording the number of emerged seedlings until the twelfth day after sowing. In order to calculate the emergence speed index (ESI) the equation suggested by Maguire (1962) was used: $ESI=N_1/D_1 + N_2/D_2 + N_n/D_n$, where N_1= number of seedlings emerged on the first day; N_n= accumulated number of emerged seedlings; D_1= first count day; D_n= number of days counted after sowing.

Total length of the seedlings shoot and root: five subsamples of 20 seeds each were used per replication, totalizing 400 seeds per treatment. Seeds were distributed on paper towel rolls and dampened with distilled water in the proportion of 2.5 times the dry paper mass, and kept in a germinator at 25 °C for five days (Nakagawa, 1999). Subsequently, the total length of the shoot and of the primary root of the seedlings was determined with the help of a millimeter ruler, and the results were expressed in cm.

The obtained data were analyzed in terms of normality and homoscedasticity using the Shapiro-Wilk and the Hartley tests respectively, which indicated no need for transformation. The analysis of variance was performed and averages were compared by Tukey's test at 5% probability. Analyses were executed by the computer program SISVAR - System for Analysis of Variance program (Ferreira, 2011).

Results and Discussion

For all variables there was an interaction between the factors seed vigor and spray volumes used in the IST. For the germination test, in both cultivars, the use of high vigor seeds provided higher percentages in relation to low vigor seeds, in all used spray volumes (Table 3). This response is due to the difference in the deterioration stage of seeds with different vigor levels. According to Marcos-Filho (2015), deterioration is a process starting from the physiological ripeness; it occurs at a progressive pace and contains a hypothetical sequence, culminating with the death of seeds. Thus, seeds that are at an advanced deterioration stage, such as the low vigor ones, presented a decrease in the transpiration rate and in the synthesis of ATP, as well as alterations in enzymatic systems, protein synthesis and mobilization of stocks, which consequently reduced their germination potential.

Supporting the results obtained for germination, Henning et al. (2010) reported that soybean seeds with higher vigor have a higher capacity to mobilize stocks during the germination process, resulting in seedlings with better initial development.

Another aspect to highlight was the high germination percentage of seeds at the beginning of the test, after its characterization. For the cultivar BRS 360 RR, the percentages were 96 and 92% and for the cultivar BRS 1010 IPRO were 93 and 86%, for high and low vigor seeds, respectively (Table 1). According to Martins et al. (2009) in comparative studies among lots with different vigor levels, it is fundamental that both present similar germination and within the commercialization standards, since the deterioration process starts with the reduction of various attributes of seed performance and vigor, resulting in the end in the loss of their germination capacity.

On low vigor seeds, in both cultivars, spray volumes above 600 mL caused decreases in the germination of seeds. As for high vigor seeds, volumes above 1800 mL for the cultivar BRS 360 RR and 1200 mL for the cultivar BRS 1010 IPRO reduced the germination potential (Table 3). For high vigor seeds the decrease according to the increase in spray volumes did not result in germination percentages below 80%, which is the minimum value required for commercialization (MAPA, 2013). Segalin et al. (2013) obtained similar results working with soybean seeds treated with spray volumes up to 1400 mL. 100 kg^{-1}, classified in sieves with different diameters.

As for low vigor seeds, the accentuated germination decrease may have occurred due to the quick soaking of seeds because of the increase in spray volumes. According to Vieira et al. (2002) high vigor seeds have the capacity to endure greater disorders caused during the soaking process by reorganizing cells and maintaining membrane integrity. On the other hand, in low vigor seeds this behavior is damaged. According to Bewley and Black (1994), deteriorated seeds absorb water more rapidly this is associated to the higher

Table 3. Germination (G), first count of the germination test (FCG), seedling emergence in sand (SE), emergence speed index (ESI) of soybean seeds from the cultivars BRS 360 RR and BRS 1010 IPRO, with two vigor levels [high (HV) and low (LV)], treated industrially with different spray volumes.

Volumes[1]	G (%)		FCG (%)		SE (%)		ESI	
	HV	LV	HV	LV	HV	LV	HV	LV
--------------- BRS 360 RR ---------------								
0	96 Aa	88 Ab	94 Aa	87 Ab	95 Aa	84 Ab	23.74 ABa	18.02 Ab
600	94 Aa	81 Bb	89 ABa	58 Bb	96 Aa	58 Ab	24.68 Aa	11.23 Bb
1200	90 ABa	57 Cb	86 BCa	38 Cb	95 Aa	57 Bb	21.95 BCa	11.16 Bb
1800	88 Ba	33 Db	86 BCa	28 Db	94 Aa	49 Bb	21.80 BCa	9.07 BCb
2400	85 Ba	20 Eb	82 Ca	20 Db	93 Aa	37 Cb	21.42 Ca	7.03 Cb
C.V (%)	4.04		4.43		7.29		6.36	
--------------- BRS 1010 IPRO ---------------								
0	98 Aa	89 Ab	96 Aa	77 Ab	95 Aa	83 Ab	23.22 Aa	18.72 Ab
600	93 Aa	80 Bb	89 Aa	54 Bb	94 ABa	56 Bb	22.77 ABa	12.81 Bb
1200	81 Ba	60 Cb	85 Ba	41 Cb	94 ABa	41 Cb	22.77 ABa	9.37 Cb
1800	83 Ba	44 Cb	76 Ba	31 Db	93 ABa	39 Cb	21.76 BCa	8.26 Cb
2400	81 Ba	43 Cb	76 Ba	30 Db	85 Ba	37 Cb	19.56 Ca	7.96 Cb
C.V (%)	6.63		8.76		6.13		6.93	

Averages followed by the same letter, lowercase letter in the line and capital letter in the column, do not differ among themselves by Tukey's test at 5% probability.

[1]Spray volumes: mL. 100kg^{-1} of seeds.

permeability of the membranes. The prejudicial effects of seed quick soaking may be the main cause of the decrease in the germination capacity of seeds, since it is the reorganization speed of the membrane system that reflects the vigor of seeds (Tilden and West, 1985).

In works developed by Costa et al. (2002) and Silva and Villela (2011), authors observed that soybean seeds with lower physiological quality presented higher water absorption rates during the first hours of the soaking process. Rossetto et al. (1997) observed that the decrease in the soaking speed of soybean seeds reduced damages caused by soaking.

In the first count of germination test, results referring to the comparison between seed vigor levels supported the ones observed in the germination test (Table 3). According to Schuch et al. (1999), more vigorous seeds presented higher speed in the metabolic processes, providing the quicker and more even emission of the primary root in the germination process, helping the growth rate of seedlings.

As for volumes, in high vigor seeds reductions were observed starting from 1200 mL. $100kg^{1}$, compared to the control sample (Table 3). In low vigor seeds, reductions were verified from 600 mL. $100kg^{-1}$, thus inferring that less vigorous seeds are more susceptible to soaking-related damages, event at lower volumes.

In addition to the effects of seed vigor and increase of spray volume over the soaking process, discussed in the germination variable, some authors report that the kind of used vehicle may also influence the soaking process of seeds. Different vehicles for water provide different soaking rates, diminishing or accentuating the risks for damages to the embryonic axis, caused by quick soaking (Farooq et al., 2012; Sediyama et al., 2012; Almeida et al., 2015).

As for the emergence of seedlings in sand, high vigor seeds presented higher percentages in both cultivars (Table 3). Hamman et al. (2002) and Kolchinski et al. (2005) also observed that the use of lots with more vigorous soybean seeds provided greater seedling emergence in comparison with less vigorous lots.

The increase in the spray volumes used for the industrial treatment reduced seedling emergence for low vigor seeds (Table 3); this reduction occurred with 1200 mL $100kg^{-1}$ and 600 mL $100kg^{-1}$ for the cultivars BRS 360 RR and BRS 1010 IPRO, respectively. For high vigor seeds from the cultivar BRS 1010 IPRO, differences were observed only between volumes of 0 and 2400 mL. $100kg^{-1}$.

As for the emergence speed index (ESI), results were similar to the ones observed in the emergence of seedlings for the comparison between vigor levels, in both cultivars (Table 3). Thus, high vigor seeds presented higher emergence percentage and speed, producing seedlings with higher competitive ability to capture and use the resources of the mean. In addition to this, Floss (2008) and Panozzo et al. (2009) verified that the seedling emergence anticipation provided a longer period of vegetative growth of the cultures, leading to a higher accumulation of photo-assimilated compounds because of the higher CO_2 inflow and, consequently, higher growth rate.

In addition, for ESI there were reductions in the results for low vigor seeds according to the spray volume increase, in both cultivars, which were reducing with the use of 600 mL. $100kg^{-1}$ (Table 3). As for high vigor seeds, volumes above 1200 mL for the cultivar BRS 360 RR and 1800 mL for the cultivar BRS 100 IPRO reduced the ESI, respectively.

As for seedling growth, evaluated by the total length test, it was possible to observe greater length in seedlings coming from high vigor seeds, for both cultivars (Table 4). Supporting the results by Vanzolini and Carvalho (2002) and Henning et al. (2010), Kolchinski et al. (2006) also verified that soybean plants coming from more vigorous seeds presented higher growth rates, as well as wider leaf area and dry matter production.

In both cultivars, the increase in the spray volumes applied in low vigor seeds reduced the total length of plants (Table 4). As for high vigor seeds, reductions were observed starting from 1200 mL. $100kg^{-1}$. Values obtained for the cultivar BRS 360 RR at volumes of 0, 600, 1200 and 1800 mL. $100kg^{-1}$, and for the cultivar BRS 284 at volumes of 0 and 600 mL. $100kg^{-1}$, demonstrated that the average total length was higher than 27.0 cm; this value was used by Vanzolini and Carvalho (2002) to classify soybean seeds as more vigorous.

As for the shoot length, high vigor seeds presented higher values in both cultivars (Table 4). For low vigor seeds from the cultivar BRS 360 RR, the spray volume increase provided reduction in the shoot length of soybean seedlings with 600 mL. $100kg^{-1}$ (Table 4). For the cultivar BRS 1010 IPRO, reductions in the shoot length were observed starting from 1800 mL. $100kg^{-1}$.

High vigor seeds from the cultivar BRS 360 RR presented lower shoot length starting from 1200 mL. $100kg^{-1}$, whereas for the cultivar BRS 1010 IPRO reductions were observed with volumes of 2400 mL. $100kg^{-1}$.

As for root length, in both cultivars, seedlings coming from high vigor seeds presented greater root growth in relation to low vigor seeds (Table 4).

In both cultivars, for low vigor seeds, there was a decrease in the root length with the increase in spray volumes (Table 4). As for high vigor seeds from the cultivars BRS 360 RR and BRS 1010 IPRO, reductions were observed starting from 1800 and 1200 mL. $100kg^{-1}$, respectively.

Table 4. Total seedling length (TSL), shoot length (LAP) and root length (RL) of soybean seeds from the cultivars BRS 360 RR and BRS 1010 IPRO, with two vigor levels [high (HV) and low (LV)], treated industrially with different spray volumes.

Volumes[1]	TSL (cm)		LAP (cm)		RL (cm)	
	HV	LV	HV	LV	HV	LV
--------------- BRS 360 RR ---------------						
0	30.02 Aa	19.12 Ab	10.62 Aa	9.47 Ab	18.50 Aa	9.37 Ab
600	28.70 ABa	15.22 Bb	9.77 ABa	8.45 Bb	19.40 Aa	6.80 Bb
1200	28.12 BCa	12.22 Cb	9.60 Ba	7.60 Bb	17.57 ABa	4.65 Cb
1800	27.17 BCa	9.17 Db	9.22 Ba	5.17 Cb	15.60 BCa	4.42 Cb
2400	23.20 CDa	9.32 Db	8.60 Ba	4.70 Cb	14.65 Ca	3.72 Cb
C.V (%)	5.57		6.97		8.03	
--------------- BRS 1010 IPRO ---------------						
0	24.82 Aa	19.55 Ab	7.52 Aa	6.55 Ab	18.30 Aa	12.02 Ab
600	26.12 Aa	11.97 Bb	7.85 Aa	6.50 Ab	18.27 Aa	5.37 Bb
1200	20.92 Ba	11.05 Bb	6.60 Aa	6.12 Ab	14.40 Ba	4.99 BCb
1800	18.07 Ca	9.52 BCb	6.40 Aa	5.37 Bb	11.47 Ca	4.17 Cb
2400	12.32 Da	7.30 Cb	5.07 Ba	4.20 Cb	7.25 Da	2.77 Db
C.V (%)	8.53		10.70		9.11	

Averages followed by the same letter, lowercase letter in the line and capital letter in the column, do not differ among themselves by Tukey's test at 5% probability.

[1]Spray volumes: mL. 100kg^{-1} of seeds.

The results observed in the seedling growth demonstrated that the shoot length test presented lower responses in relation to spray volumes and vigor levels of seeds (Table 4). Thus, the root length test (Table 4), appeared to be the most suitable parameter to differentiate lots with differences in seed vigor, as reported by Schuch et al. (1999) and Vanzolini et al. (2007).

The higher sensitivity of the root length test may be related to the structure of soybean seeds and to the germination process, since soybean seeds have, within their external structures, the micropyle-hilum area. According to Peske and Peske (2011), this area generally has higher permeability to water, and it is responsible for approximately 20% of its flow during the first 24 hours of seed hydration. Thus, after applying the spray volumes on seeds, part of them is deposited and absorbed by the micropyle-hilum area. Thus, along the germination process, the radicle is the first structure of the embryo that develops and the first to be touched by the chemical product; phytotoxicity may occur, reducing the length of roots.

The tested cultivars responded similarly to the vigor levels of seeds and to treatments with different spray volumes. Thus, it becomes essential to use lots of high vigor soybean seeds in the industrial treatment, due to the attenuation effect that the chemical treatment causes over low vigor seeds, reducing their quality in an accentuated way as spray volumes increase.

Conclusions

At different spray volumes, high vigor soybean seeds present higher physiological quality in relation to low vigor seeds.

The increase in the spray volume while treating seeds reduces the physiological quality of low vigor soybean seeds.

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