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DOES CHEMICAL DESICCATION AND HARVEST TIME AFFECT THE PHYSIOLOGICAL AND SANITARY QUALITY OF SOYBEAN SEEDS?[1]

ALAN MARIO ZUFFO[2]*, MARIELY DE ABREU DOS SANTOS[2], IZABELA CRISTINA DE OLIVEIRA[2], CHARLINE ZARATIN ALVES[2], JORGE GONZÁLEZ AGUILERA[2], PAULO EDUARDO TEODORO[2]

ABSTRACT - The use of desiccants may result in seeds with high physiological and sanitary quality due to the shorter period of exposure to field adverse conditions before the maturity stage for harvest. This study evaluated the effect of chemical desiccants and harvest times on the physiological and sanitary quality of soybean seeds. The experiment consisted of a randomized block design, arranged in a factorial scheme (4 × 3) + 1, with four replications. The first factor corresponded to four desiccation (grammoxone–2 L ha^{-1}, glufosinate –2 L ha^{-1}, reglone–1.5 L ha^{-1}, and saflufenacil–40 g ha^{-1}) applied at the $R_{7.1}$ phenological stage (physiological maturity and 65% moisture with three harvest times (0, 7, and 14 days after the R_8 phenological stage) and additional treatment (control, application of water only, and harvest at the R_8 stage), with four replications. The use of the grammoxone desiccant and seeds harvested at seven days after the R_8 stage resulted in soybean seeds of the highest physiological quality, as observed for the variables germination, moisture damage, mechanical damage, and incidences of *Colletotrichum* sp., *Phomopsis* sp., *Penicillium* sp. *Fusarium* sp., *Cercospora kikuchii*, and *Alternaria* sp. Seeds harvested at the R_8 + 14 stage had the greatest losses in seed quality. The use of ammonium glufosinate and saflufenacil as desiccants is not recommended due to the reduction in the physiological quality of soybean seeds.

Keywords: *Glycine max*. Herbicides. Physiological maturity. Vigor.

A DESSECAÇÃO QUÍMICA E A ÉPOCA DE COLHEITA AFETAM A QUALIDADE FISIOLÓGICA E SANITÁRIA DE SEMENTES DE SOJA?

RESUMO - O uso de dessecantes pode permitir a obtenção de sementes com máxima qualidade fisiológica e sanitária, devido o menor período em que as sementes ficam expostas as condições adversas no campo aguardando o estádio de maturação para colheita. O objetivo neste trabalho foi avaliar o efeito de dessecantes químicos e épocas de colheita sobre a qualidade fisiológica e sanitária em sementes de soja. O ensaio foi realizado em delineamento em blocos casualizados, disposto em esquema fatorial (4 × 3) + 1, sendo quatro herbicidas para a dessecação (gramoxone - 2 L ha^{-1}, glufosinato – 2 L ha^{-1}, reglone – 1,5 L ha^{-1}, saflufenacil 40 g ha^{-1}) aplicado no estádio fenológico $R_{7.1}$ (maturidade fisiológica e 65% de umidade), com três épocas de colheita (0; sete e 14 dias após o estádio fenológico R_8 - maturação plena), mais o controle (ausência de dessecante e colhida em R_8), com quatro repetições. O uso do dessecante gramoxone e as sementes colhidas sete dias após R_8 proporciona maior qualidade fisiológica de sementes de soja, conforme observado nas variáveis germinação, danos por umidade, danos mecânicos e a incidência de *Colletotrichum* sp., *Phomopsis* sp., *Penicilium* sp., *Fusarium* sp., *Cercospora kikuchii* e *Alternaria* sp.. A colheita de sementes no estádio R_8+14 promove as maiores perdas na qualidade das sementes. O uso de glufosinato de amônio e saflufenacil como dessecantes não são recomendados, devido à redução na qualidade fisiológica das sementes de soja.

Palavras-chave: *Glycine max*. Herbicidas. Maturidade fisiológica. Vigor.

*Corresponding author
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[2]Department of Agronomy, Universidade Federal de Mato Grosso do Sul, Chapadão do Sul, MS, Brazil; alan_zuffo@hotmail.com – ORCID: 0000-0001-9704-5325, mariely.abreus@hotmail.com – ORCID: 0000-0002-7419-0252, izabelamarangon@gmail.com – ORCID: 0000-0002-4666-801X, charline.alves@ufms.br – ORCID: 0000-0001-6228-078X, j51173@yahoo.com – ORCID: 0000-0002-7308-0967, eduteodoro@hotmail.com – ORCID: 0000-0002-8236-542X.

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] has high economic relevance, and thus producing seeds with high physiological and sanitary quality is essential for the formation of vigorous crops. In the soybean production process, harvesting should be carried out as carefully as possible as relates to the physiological maturity stage, which is affected by the high water content in the seeds (TERASAWA et al., 2009). The process of seed deterioration is irreversible. Its manifestation occurs over time, and it can be delayed depending on the storage conditions (CARDOSO et al., 2012). Thus, chemical desiccation is an alternative to minimize seed quality losses in the field and anticipate the harvest (BOTELHO et al., 2016). The use of desiccant herbicides may accelerate the process of water loss in plants and consequently in seeds (TOLEDO; CAVARIANI; FRANÇA NETO, 2012). Daltro et al. (2010) anticipated the soybean harvest by about two days while using the herbicides grammoxone, reglone, grammoxone + reglone, and grammoxone + diuron. Kappes et al. (2009) found similar results by anticipating the harvest by two days. The authors verified that seed lots desiccated with grammoxone had better performance in some quality tests.

In addition, seed quality is related to the moisture content close to the harvest time. Crop management with desiccants and the choice of the best harvest time are determinants at this stage (MOREANO et al., 2013). For Zuffo et al. (2017a,b), the delay in the soybean seed harvest at ten days after the R_8 stage impaired seed vigor, and after 15 days, germination was decreased.

The main aspects regarding the pre-harvest use of desiccants on soybeans are the choice of the herbicide and the ideal time for the application, minimizing damages to the yield and most importantly the physiological quality of the seeds (GUIMARÃES et al., 2012). Moreover, the harvest time is critical in the production process due to the possibility of losses to the physiological and sanitary quality of soybean seeds. Thus, this study evaluated the effect of chemical desiccants and harvest times on the physiological and sanitary qualities of soybean seeds.

MATERIAL AND METHODS

The experiment was carried out in the 2013/2014 agricultural year at the Centro de Desenvolvimento Científico e Tecnológico em Agropecuária–Fazenda Muquém/UFLA, located in the municipality of Lavras, MG (lat. 21°14' S, long. 45°00'W, alt. 918 m), at the Seed Central Laboratory of the Department of Agriculture of the Federal University of Lavras, MG. The soil of the experimental area is classified as a Rhodic Hapludox or a Latossolo Vermelho Eutroférrico, under the Brazilian classification (EMBRAPA, 2013). The chemical and physical composition of the soil is shown in Table 1.

Table 1. Chemical and physical composition of the LVdf soil (0-0.20 m) before the experiment installation. Lavras - MG, in the 2013/2014 agricultural year.

pH	Ca^{2+}	Mg^{2+}	Al^{3+}	$H^{+}+Al^{3+}$	SB	CEC	P	K	OM	V
H_2O	- - - - - - - - - - - - $cmol_c\ dm^{-3}$ - - - - - - - - - - - - - - -						- - $mg\ dm^{-3}$ - -		$Dag\ kg^{-1}$	%
6.4	5.0	1.4	0	2.9	6.7	9.6	11.46	118	3.41	69.82
Zn	Mn	Cu	B	Fe	S	Clay	Silt	Sand	Textural Class	
- - - - - - - - - - - - $mg\ dm^{-3}$ - - - - - - - - - - -						- - - $dag\ kg^{-1}$ - - -			- - - -	
4.97	31.70	1.40	0.17	34.81	4.75	64	20	16	Clayey	

H + Al: potential acidity; SB: sum of bases; CEC: cation exchange capacity at the pH 7.0; OM: organic matter; V: bases saturation.

The climate of the region is type Cwa, according to Köppen's classification, with an average annual temperature of 19.3 °C and a normal annual rainfall of 1,530 mm (DANTAS; CARVALHO; FERREIRA, 2007). During the seed production process, the climatic data were collected at the meteorological station of the Instituto Nacional de Meteorologia (INMET) located at the Federal University of Lavras-UFLA, shown in Figure 1a. Weather conditions during the seed harvest times are shown in Figure 1b.

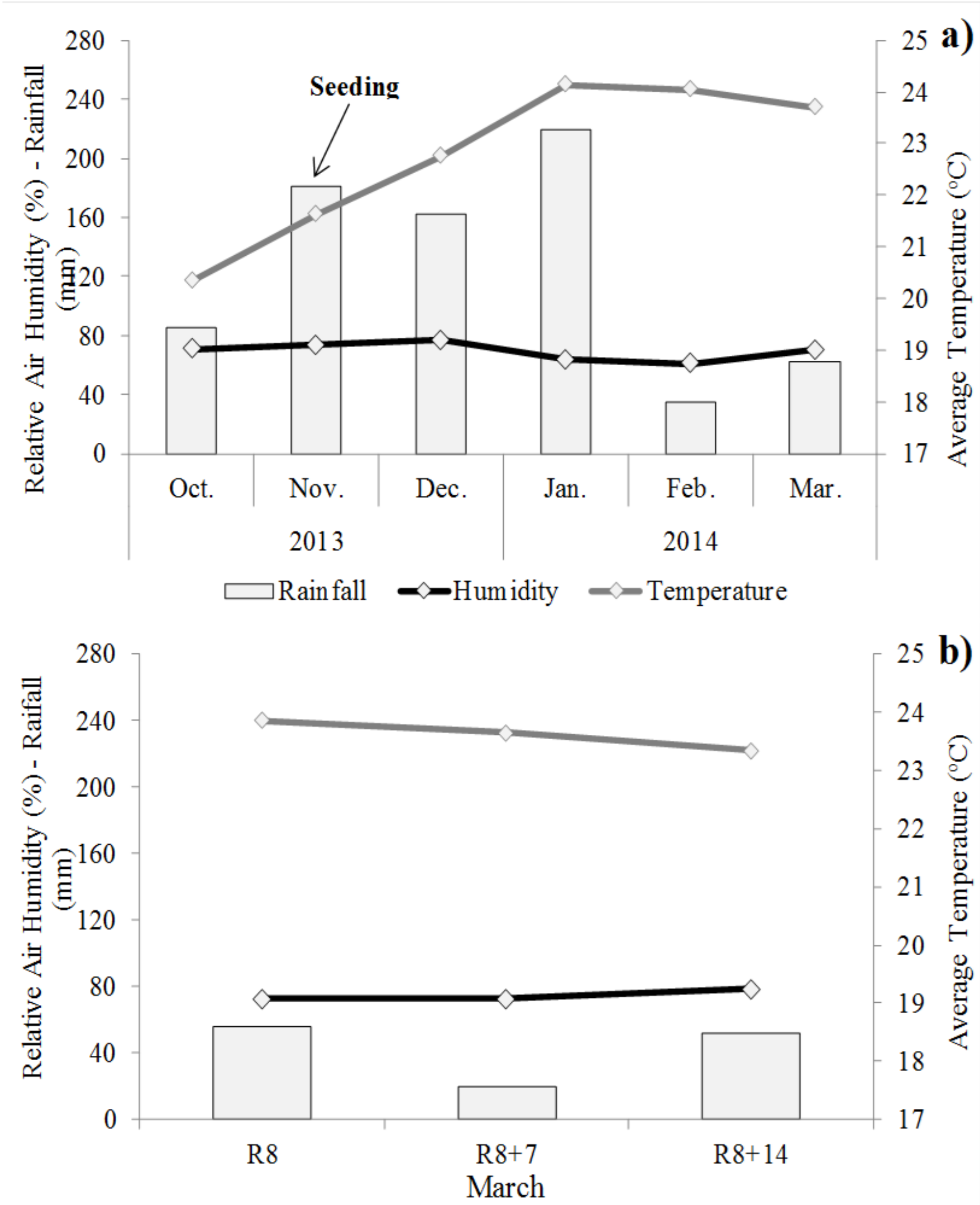

Figure 1. Monthly averages of rainfall, relative air humidity, and air temperature in Lavras-MG, in the 2013/2014 agricultural year, during the production of soybean seeds (a) and at seeds harvest times (b). Source: INMET.

The experiment consisted of a randomized block design, arranged in a factorial scheme (4 × 3) + 1, with four replications. The first factor corresponded to four desiccation herbicides (grammoxone–2 L ha^{-1}, glufosinate–2 L ha^{-1}, reglone –1.5 L ha^{-1}, saflufenacil–40 g ha^{-1}), applied at the $R_{7.1}$ phenological stage (physiological maturity and 65% moisture). The second factor was composed of three harvest times [0, 7, and 14 days after the R_8 phenological stage -, according to Fehr et al. (1971)] and additional treatment (control, application of water only, and harvest at the R_8 stage). The desiccant chemicals were applied using a motorized backpack sprayer, coupled to a boom with four spraying tips (XR 110.02), with a volume of 200 L ha^{-1}. Sowing was carried out on November 15. Seeds had been previously treated with pyraclostrobin + methyl thiophanate + fipronil (Standak Top®), at a dose of 2 mL p. c. kg^{-1} of seed and inoculated with *Bradyrhizobium japonicum* (Nitragin Cell Tech®) at the dose of 3 mL p. c. kg^{-1} of seed (strains SEMIA 5079 and 5080). Fertilizer application consisted of 350 kg ha^{-1} of a N-P_2O_5-K_2O (02-30-20) formulation, applied in the furrow. Each plot had four 5-m rows, spaced at 0.50 meters apart. The two central rows were considered the useful area, with scraping 1 meter from each end. This work used the soybean cultivar BRS 820 RR®, with a seeding density of 12 plants per linear meter totaling a population density of 240,000 plants ha^{-1}.

The herbicides glyphosate, pyraclostrobin + epoxiconazole, azoxystrobin + cyproconazole, teflubenzurom, chlorpyrifos, and cypermethrin were used for weed, pest, and disease control during plant developmental stages.

After desiccation, plants were harvested at three different times: at the phenological stage R_8, full maturation, and with a delay of 7 and 14 days after R_8, with an additional treatment as control (water application only at the R_7 stage and harvested at R_8 stage). Harvest was carried out manually. Afterward, plants were threshed mechanically in a grain thresher (Vencedora Maqtron® model B-380). Seeds were stored in 'Kraft' paper bags and dried in the shade with temperature of 25 ± 2 °C until reaching 13% moisture. After checking the adequate moisture content, samples were homogenized and sieved. Seeds retained in sieves (6 mm) were used for analyses.

The physiological quality of the seeds was evaluated by the following variables:

Moisture content: after drying in the shade, seeds were subjected to the determination of the percentage of water content by the oven method, at 105 °C (± 3 °C), for 24 h, according to Brasil (2009).

Germination (GER): seeds were distributed on germitest paper, moistened with a volume of distilled water equivalent to 2.5 times that of the non -hydrated paper, which was in the form of rolls. Treatments consisted of 50 seeds, with four replications. Afterward, treatments were stored in a BOD chamber, at 25 °C. Plants were evaluated at eight days after sowing, according to Brasil (2009).

Tetrazolium (TZ): seeds were stored in previously moistened germitest paper for 16 hours, at 25 °C. Afterward, seeds were placed in plastic containers and were completely submerged in a 0.075% tetrazolium solution, remaining for three hours, at 40 °C, in a BOD chamber. Then, seeds were washed in water and the percentages of viability (TZ_{1-5}), vigor (TZ_{1-3}), bedbug damage (TZ_{SBD}), mechanical damage (TZ_{MEC}), and moisture damage (TZ_{MOI}) were determined, according to França Neto et al. (1998).

Seed sanity: this parameter was evaluated by the blotter-test method, with five replications of 40 seeds, according to Machado (2000), with modifications. The Petri dishes were kept in an incubation room at 20 °C, with a 12-h photoperiod, for seven days. After this period, they were evaluated for the presence of pathogens associated with the seeds.

Data were subject to analysis of variance using Sisvar® version 5.3 software for Windows (Statistical Analysis Software, UFLA, Lavras, MG, BRA) (FERREIRA, 2011), by the F test at 5% probability, and means comparison by Tukey's test at 5% probability.

RESULTS AND DISCUSSION

Results showed significant effects for the H × T (Herbicide × Time) interaction for germination, moisture damage, mechanical damage, and incidence of *Phomopsis* sp., *Fusarium* sp., *Cercospora kikuchii*, and *Alternaria* sp. (Table 2). Conversely, the factorial × additional interaction revealed a significant effect for the variables germination, moisture damage, and incidence of *Penicillium* sp. and *Fusarium* sp. For the other variables, the interaction was not significant, indicating that the use of herbicides at the pre-harvest and harvest times could be studied separately. Regarding the soybean seeds from plants subject to desiccation and harvested at different times, a significant isolated effect ($p < 0.05$) on bedbug damage was observed (Table 2). Zuffo et al. (2017a, b) also found a significant effect of delayed soybean harvest on bedbug damage.

Table 2. Analysis of variance (mean square values) for the variables moisture content (MC), germination (G), tetrazolium vigor (TZ_{1-3}), tetrazolium viability (TZ_{1-5}), bedbug damage (TZ_{BD}), moisture damage (TZ_{MOI}), mechanical damage (TZ_{MEC}), and the presence of the fungi *Colletotrichum* (COL), *Phomopsis* (PHO), *Penicillium* (PEN), *Aspergillus* (ASP), *Fusarium* (FUS), *Cercospora kikuchii* (CK) and *Alternaria* (ALT) evaluated in soybean seeds from plants subject to pre-harvest desiccant herbicides and harvested at different times.

Source of variation	MC	GER	TZ_{1-3}	TZ_{1-5}	TZ_{BD}	TZ_{MOI}	TZ_{MEC}
Herbicide (H)	0.51^{ns}	229.58*	277.14^{ns}	64.67^{ns}	109.18*	130.91*	6.40^{ns}
Time (T)	0.02^{ns}	393.58*	391.02^{ns}	18.58^{ns}	222.25*	429.19*	7.19^{ns}
H x E	0.12^{ns}	381.92*	326.28^{ns}	45.69^{ns}	74.87^{ns}	206.52*	11.15*
Factorial x additional	0.19^{ns}	630.02*	58.88^{ns}	7.69^{ns}	2.76^{ns}	98.77*	14.36^{ns}
Error	0.25	67.77	248.20	45.79	35.35	19.87	4.49
CV	6.37	11.86	18.45	7.33	30.75	31.90	33.75
SV	COL	PHO	PEN	ASP	FUS	CK	ALT
Herbicide (H)	0.83^{ns}	19.30^{ns}	1.67^{ns}	0.83^{ns}	457.50*	11.25*	35.69^{ns}
Time (T)	0.31^{ns}	12.91^{ns}	3.75^{ns}	1.67^{ns}	418.43*	6.35*	119.47^{ns}
H x T	1.56^{ns}	24.30*	2.91^{ns}	0.83^{ns}	315.93*	4.68*	274.75*
Factorial x additional	1.15^{ns}	30.80^{ns}	41.53*	0.51^{ns}	508.84*	0.03^{ns}	70.80^{ns}
Error	1.15	9.03	1.44	1.05	89.90	1.82	46.15
CV	23.30	14.90	16.20	32.80	28.10	14.10	24.20

^{ns} e *: not significant and significant at the 5% of probability by the F test, respectively. CV – coefficient of variation.

For percentages of germination, moisture damage, and incidence of *Penicillium* sp. and *Fusarium* sp., the highest means were observed in treatments that used seeds from desiccated plants and harvested at different times (factorial) (Table 3). These results are similar to those obtained by Santos et al. (2018), who verified a decrease in the percentage of soybean germination due to the use of desiccant herbicides (grammoxone + reglone) at the pre-harvest stage. However, pathogenic fungi infestation was favored. This fact may be attributed to the higher amount of moisture damage in seeds from plants that were desiccated and harvested at different times (factorial); thus, the seeds released more exudates resulting in a greater incidence of *Penicillium* and *Fusarium* fungi.

Table 3. Means Comparison of the between factorial and additional interaction for germination, moisture damage, and incidence of *Penicillium* and *Fusarium* fungi, evaluated in soybean seeds from plants subject to desiccant herbicides at the pre-harvest stage and harvested at different times.

Source of variation	Germination (%)	Moisture Damage (%)	*Penicilium* (%)	*Fusarium* (%)
Factorial	69.42 a	13.97 a	3.50 a	26.00 a
Aditional	54.33 b	8.00 b	0.50 b	15.50 b

Means followed by the same letters in the same column do not differ from each other by the F test.

Increases in the seed germination with the use of desiccants may be due to the maturation uniformity caused by the desiccant, which reduces the exposure time to unfavorable climatic conditions, a fact that may result in losses in physiological quality and impair the germination of the seeds (BÜLOW; CRUZ-SILVA, 2012). At the same time, an increase in moisture damages was observed, possibly due to the delay in harvesting and the unfavorable climatic conditions of the field storage, verified by the incidence of rainfall (Figure 1). According to Lacerda et al. (2005), desiccant herbicides may leave residues and thus reduce seed vigor and fungal development in the legume stems, and seeds. However, despite the higher incidence of *Penicillium* sp. and *Fusarium* sp., these pathogens did not inhibit seed germination. According to Carvalho and Nakagawa (2012), the pathogens carried by seeds do not necessarily imply the transmission of these agents to progeny, since several factors can act on this feeling.

In soybean seeds from plants subjected to desiccant herbicides applied pre-harvest, the greatest bedbug damage was verified with the use of reglone, saflufenacil, and grammoxone products (Table 4). Regarding the harvest time, the highest bedbug damages were observed at the R_8 + 14 stage. These data are similar to those obtained by Zuffo et al. (2017b), who verified a higher percentage of seeds damaged by bedbugs with harvest delayed after R_8, mainly with 20 days of delay.

Table 4. Means of the desiccant herbicides and the harvest times for bedbug damage in soybean seeds.

Herbicide	Bedbug damage (%)
Reglone	21.00 a
Ammonium glufosinate	14.11 b
Saflufenacil	21.22 a
Grammoxone	21.00 a
Harvest time	
R_8	17.50 b
R_8+7	16.25 b
R_8+14	24.25 a

Means followed by the same letters in the same column do not differ by the Tukey´s test at the 5% of probability.

For bedbug damage, soybean seeds from herbicide-desiccated plants had an incidence of attacks higher than 14%. Pest and microorganism attacks, as well as rainfall at the pre-harvest stage, are examples of field conditions to which the seed is subject until harvest (VEIGA et al., 2007). Rainfall periods provide favorable conditions for the development of insects due to climatic conditions and food supply. These conditions were favorable for the attack of pests and microorganisms during harvest times, as observed in Figure 1b.

Regarding the germination, no statistical differences among the harvest times were verified for seeds from plants desiccated with reglone and ammonium glufosinate herbicides (Table 5). Seeds from plants sprayed with saflufenacil and harvested at the R_8 stage showed lower germination values. Conversely, desiccation with grammoxone and R_8 + 7 revealed seeds with higher germination percentages. Regardless of the soybean harvest time, the desiccation of soybeans with ammonium glufosinate and saflufenacil herbicides inhibited germination. Similar results were obtained by Delgado, Coelho and Buba (2015) and Botelho et al. (2016), who verified that ammonium glufosinate was the desiccant herbicide that resulted in the lowest germination values.

Table 5. Unfolding of the harvest times x herbicides interaction evaluated in soybean seeds.

Herbicide	R_8	R_8+7	R_8+14
		Germination (%)	
Reglone	73.67 aA	79.67 aA	74.00 aA
Ammonium glufosinate	69.00 bA	60.67 bA	68.33 abA
Saflufenacil	49.33 bB	75.00 abA	70.00 abA
Grammoxone	70.33 bB	88.67 aA	54.33 bB
		Moisture Damage (%)	
Reglone	5.00 bC	32.00 aA	22.00 aB
Ammonium glufosinate	14.33 aA	14.33 bA	9.00 bA
Saflufenacil	4.33 bB	15.00 bA	16.67 abA
Grammoxone	4.67 bB	6.67 bB	23.67 aA
		Mechanical Damage (%)	
Reglone	5.67 aA	8.33 aA	7.33 abA
Ammonium glufosinate	6.33 aA	5.33 aA	7.33 abA
Saflufenacil	5.67 aA	6.33 aA	3.33 bA
Grammoxone	4.00 aA	6.00 aA	9.67 aA
		Phomopsis sp. (%)	
Reglone	2.00 bA	1.00 aA	3.00 aA
Ammonium glufosinate	7.00 aA	0.00 aB	3.00 aB
Saflufenacil	1.50 bA	3.50 aA	5.00 aA
Grammoxone	1.50 bA	1.50 aA	0.00 aA
		Fusarium sp. (%)	
Reglone	15.50 bA	3.50 aA	4.00 bA
Ammonium glufosinate	33.50 aA	17.00 aA	11.00 abB
Saflufenacil	12.50 bA	16.50 aA	24.00 aA
Grammoxone	19.50 abA	7.50 aB	21.50 aA
		Cercospora kikuchii (%)	
Reglone	0.00 aA	2.00 aA	1.50 bA
Ammonium glufosinate	0.00 aA	0.00 aA	0.00 bA
Saflufenacil	1.00 aB	1.00 aB	4.00 aA
Grammoxone	0.50 aA	0.50 aA	0.50 bA
		Alternaria sp. (%)	
Reglone	24.50 aA	8.50 aB	5.50 bB
Ammonium glufosinate	9.00 bB	15.00 aAB	22.50 aA
Saflufenacil	20.50 aA	16.50 aA	10.00 bA
Grammoxone	16.50 abA	19.50 aA	13.00 bA

Means followed by the same lower-case letters in the same column and the same upper-case letter in the same row do not differ from each other by the Tukey's test at the 5% of probability.

The mechanism of action may cause the negative effect of saflufenacil herbicide/desiccant on the germination of soybean seeds. According to Grossmann et al. (2010), saflufenacil is an inhibitor of the protoporphyrinogen IX oxidase enzyme (PPO or PROTOX), which catalyzes the conversion of PPO-IX into protoporphyrin IX. The difficulty of completing this metabolic pathway impairs the synthesis of chlorophyll and cytochromes in the chloroplast, besides generating reactive oxygen species in the cytosol, with subsequent oxidative stress in the membranes and extravasation of the cellular content (BEALE; WEISTEIN, 1990) and possible inhibition of germination, as found in this study. In turn, the herbicide gramoxone is a photosystem I inhibitor in the tilacoid membranes, which accept electrons from the photosystem I primary acceptors and then react with oxygen to form superoxide that is harmful to chloroplasts (TAIZ et al. 2017).

Ammonium glufosinate causes the accumulation of ammonia in treated plants. The action mode is due to the inhibition of the enzyme glutamine synthetase, responsible for the conversion of glutamate and ammonia into glutamine (CARVALHO, 2013). According to Lacerda et al. (2005), ammonium glufosinate has compounds in its shape that make translocation easier for the seed when compared to the herbicides gramoxone and reglone. In this study, the application of desiccants in plants occurred when the seeds had 65% water content, and this fact may have offered a greater translocation of the product to the seed, possibly inhibiting germination.

Regarding the harvest times of soybean seeds, the lowest germination means were observed for harvesting at R_8 and R_8 + 14 days. This fact is directly related to the climatic conditions at the harvest times, as shown in Figure 1b. At the stages, R_8 and R_8 +14 days, about 50 mm of rainfall was recorded, which depreciated seed quality. For the harvest carried out at R_8 + 7 days, the rainfall value was only 20 mm (Figure 1b). This fact supports the influence of climatic conditions during the harvest time on seed quality, especially due to rainfall and not only the delay). Similar results were found by Zuffo et al. (2017b), who observed that the soybean seeds harvested after the R_8 stage and subject to rainfall during this period showed lower percentages of germination.

The minimum germination of soybean seed lots in Brazil should be 80%, according to marketing standards established by the Normative Instruction No. 45 (BRASIL, 2013). Thus, pre-harvest desiccation with grammoxone and seeds harvested at 14 days after the R_8 stage showed satisfactory germination (Table 5). Given the market's requirement, the indication of germination is not sufficient (ZUFFO et al. 2017b), meaning that other indications, such as bedbug damage, mechanical damage, and pathogen incidence are mandatory. For these parameters, no harmful effect of the herbicide grammoxone was observed up to seven days after the R_8 stage.

The qualitative decrease of the physiological parameters may be related to the respiratory processes of the seeds, favored by situations of frequent rainfall during the pre-harvest time (MINUZZI et al., 2010). Thus, seed respiration is greatly influenced by water content (CARVALHO; NAKAGAWA, 2012). Therefore, rainfall at the pre-harvest stage probably accelerated the deterioration process of the physiological quality of the seeds at all harvest times. According to Marcos Filho (2005), the alternation of dry and wet periods harms the seed coat due to the loss and gain of water caused by the moisture variation. Such injuries can also act as a gateway to pathogens.

Moisture damages in soybean seeds from plant desiccation with the herbicide ammonium glufosinate were identical between the harvest times. However, the values were higher, starting from R_8 (Table 5). Seeds from plants sprayed with ammonium glufosinate had higher values of mechanical damage when the harvest was carried out at the R_8 stage. However, when harvested at 14 days after R_8, this herbicide resulted in less damage. The highest moisture damages were observed in seeds of plants desiccated with the herbicide reglone and harvested at R_8 + 7. With the use of reglone or saflufenacil desiccants, moisture damage increased starting from seven days after R_8. For the herbicide grammoxone, more damage was found at 14 days after R_8, reinforcing the relationship between harvest delay and damage by moisture. Similar results were found by Zuffo et al. (2017b), who observed an increase in moisture damage with the time that the seeds remained in the field after the R_8 stage.

Regarding the mechanical damage, seeds treated with desiccant herbicides used at the harvest times R_8 and R_8 + 7 did not differ statistically (Table 5). At the harvest time R_8 + 14, saflufenacil had lower values, and did not differ from reglone and ammonium glufosinate. Regardless of the desiccant herbicide applied, harvest times did not interfere with mechanical damage. Therefore, although the field storage of soybean seeds causes higher damages due to moisture, this fact had no relationship with mechanical damage, possibly because the plants were threshed when dried. Regarding seed sanity, the pathogens *Colletotrichum* sp., *Phomopsis* sp., *Penicillium* sp., *Aspergillus* sp., *Fusarium* sp., *Semitectum* sp., *Cercospora kikuchii*, and *Alternaria* sp were detected. These pathogens were also observed by Zuffo et al. (2017a) in soybean seeds harvested at different times. Pathogens observed in the seeds of this study are the species of higher occurrence in Brazil; they cause significant production losses and decrease the seed quality of soybean (DANELLI et al., 2011).

Table 5 shows the low incidence of *Phomopsis* sp. and *Cercospora kikuchii* in this study. Seeds from plants sprayed with reglone, saflufenacil, and grammoxone harvested at the R_8 stage had lower incidences of *Phomopsis* sp. In addition, treatments with these herbicides showed no differences between harvest times. Seeds harvested at R_8 + 7 and R_8 + 14 revealed no influence of desiccants on the incidence of this pathogen.

For the incidence of *Cercospora kikuchii*, the herbicides reglone, ammonium glufosinate, and saflufenacil had similar responses about harvest times, and were not statistically different from each other (Table 5). Saflufenacil had higher values when the seeds were harvested at 14 days after R_8. No statistical difference was observed between the herbicides applied at the R_8 and R_8 + 7 harvest times regarding the presence of *Cercospora kikuchii*. At the harvest time R_8 + 14, the seeds of plants treated with the herbicides reglone, ammonium glufosinate, and grammoxone showed lower incidences of this fungus.

Seeds from plants desiccated with reglone and saflufenacil showed the same incidence of *Fusarium* sp. For the herbicides ammonium glufosinate and grammoxone, a lower incidence of pathogens was observed when seeds were harvested at R_8 + 7 and R_8 + 14, respectively. At R_8, seeds from plants desiccated with reglone and saflufenacil herbicides showed a lower incidence of this fungus (Table 5). At R_8 + 7, no statistical differences were observed among herbicides. Conversely, the delay in 14 days after the R_8 stage revealed lower means when reglone was used. However, no differences were verified with the use of ammonium glufosinate.

The use of the ammonium glufosinate resulted in seeds with a lower incidence of *Alternaria* sp. at the harvest time R_8 (Table 5). At R_8 + 7, no statistical difference was observed among the herbicides used. Conversely, the delay in 14 days after R_8 stage resulted in lower percentages of *Alternaria* sp when reglone, saflufenacil, and grammoxone were applied. The use of ammonium glufosinate and harvest delay increased the incidence of *Alternaria* sp. from the seventh day after R_8. Seeds from plants sprayed with saflufenacil and grammoxone showed no statistical difference about harvest times.

Diniz et al. (2013a) and Zuffo et al. (2017a) verified a higher incidence of *Colletotrichum* sp., *Phenopsis* sp., *Penicillium* sp., *Aspergillus* sp., *Fusarium* sp., *Semitectum* sp., *Cercospora kikuchii*, and *Alternaria* sp. in seeds harvested at 15 days after the R_8 stage. The highest germination percentage in seeds treated with grammoxone and harvested at seven days after R_8 may be related to the lower fungal incidence, especially *Fusarium* spp.

Santos et al. (2018) observed higher pathogen infestation in seeds from plants sprayed with desiccant herbicides (grammoxone + reglone) when compared with the control treatment (no herbicide). The authors also reported that application increased the release of exudates by lower vigor seeds, causing higher seed infestation. Therefore, the high pathogen infestation in the seeds may be related to the low seed quality.

Microorganisms that attack the crop at the end of cycle may cause lesions and rotting, impairing seed quality. These damages can be reduced with application of desiccants, allowing an efficient harvest with machinery and reducing the time of field storage (MARCOS-FILHO, 2015). Seed sanity is directly related to performance and quality, and the deterioration process is associated with how pathogens can affect seed quality, physiological performance, and vigor (MINUZZI et al., 2010; MARCOS-FILHO, 2015).

CONCLUSIONS

The use of the grammoxone desiccant and seeds harvested at seven days after the R_8 stage resulted in soybean seeds of the highest physiological quality, as observed for the variables germination, moisture damage, mechanical damage, and incidences of *Colletotrichum* sp., *Phomopsis* sp., *Penicillium* sp. *Fusarium* sp., *Cercospora kikuchii*, and *Alternaria* sp.

Seeds harvested at the R_8 + 14 stage had the greatest losses in seed quality.

The use of ammonium glufosinate and saflufenacil as desiccants is not recommended due to the reduction in the physiological quality of soybean seeds.

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