PLANTA DANINHA

SBCPD
SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS
<http://www.sbcpd.org>

ISSN 0100-8358 (print)
1806-9681 (online)

Article

Physiological Quality of Carioca Bean Seeds Submitted to the Application of Desiccant Herbicides in Two Periods

Qualidade Fisiológica de Sementes de Feijão Carioca Submetidas à Aplicação de herbicidas

CASTOLDI, C.T.[1]
RADUNZ, L.L.[2]
GALON, L.[1]*
ASPIAZÚ, I.[3]
FORTE, C.T.[1]
SCARIOT, M.A.[1]
SOUZA, D.O.[1]

* **Corresponding author:** <leandro.galon@uffs.edu.br>

Received: October 23, 2018
Approved: February 7, 2019

Planta Daninha 2019; v37:e019215688

ABSTRACT - The use of herbicides for bean crop desiccation aiming seed production, is an alternative management because it allows harvesting when the seeds present high vigor, germination and dry mass, however this technique can cause damages to the seeds. The objective of this study was to evaluate the physiological quality of bean seeds, of the Carioca type, with the application of desiccant herbicides doses at different periods, aiming at the anticipation of the harvest. The bean plants, Pérola cultivar, were desiccated when the seeds had 42 and 30% water content, with ammonium glufosinate, saflufenacil and diquat at doses of 0, 50, 75 and 100% in relation to the recommended average dose for desiccation, respectively for each of the herbicides. The control treatment without desiccant application was harvested on the same date as desiccation. The additional treatment, also without desiccant application, was harvested only when the seeds had a water content of 18%. The variables analyzed were germination, first germination count, germination speed index, cold test, accelerated aging, seedling and radicle length, and dry mass. The herbicides applied in the first period (42% water), at the highest doses, impair the physiological quality of the seeds, and the seeds with water contents of 30 and 42%, without the use of desiccants, promote high vigor and germination. Satisfactory results were obtained when the saflufenacil herbicide was applied in period 2 (30% water), using 50% of the recommended average dose of this herbicide.

Keywords: *Phaseolus vulgaris,* bean desiccation, harvest anticipation.

RESUMO - A dessecação da cultura do feijão destinado à produção de sementes, com a utilização de herbicidas, é uma alternativa de manejo, pois permite a colheita quando as sementes apresentam elevado vigor, germinação e massa seca, porém essa técnica pode ocasionar prejuízos às sementes. Objetivou-se com este trabalho avaliar a qualidade fisiológica de sementes de feijão, do tipo carioca, com a aplicação de doses de herbicidas dessecantes em diferentes épocas, visando a antecipação da colheita. As plantas de feijão carioca, cultivar Pérola, foram dessecadas quando as sementes apresentavam 42% e 30% de teor de água, com amonio-glufosinate, saflufenacil e diquat, nas doses de 0%, 50%, 75% e 100% em relação à dose média recomendada para dessecação, respectivamente para cada um dos herbicidas. O tratamento controle, sem aplicação do dessecante, foi colhido na mesma data das dessecações. Já o tratamento adicional, também sem aplicação do dessecante, foi colhido apenas quando as sementes apresentavam o teor de água de 18%. As variáveis analisadas foram germinação, primeira contagem de germinação, índice de velocidade de germinação, teste de frio, envelhecimento acelerado, comprimento de plântula e radícula e massa seca. Os herbicidas

[1] Universidade Federal da Fronteira Sul, Campus Erechim, Erechim-RS, Brasil. [2] Universidade Federal do Rio Grande do Sul, Porto Alegre-RS, Brasil. [3] Universidade Estadual de Montes Claros, Campus Janaúba, Janaúba-MG, Brasil.

Doi: 10.1590/S0100-83582019370100154

aplicados na primeira época (42% de água), nas maiores doses, prejudicam a qualidade fisiológica das sementes, e a colheita das sementes com teores de água de 30% e 42%, sem a utilização de dessecantes, promove elevado vigor e germinação. Resultados satisfatórios foram constatados quando se aplicou o saflufenacil na 0 época 2 (30% de água), utilizando 50% da dose média recomendada deste herbicida.

Palavras-chave: *Phaseolus vulgaris*, dessecação do feijoeiro, antecipação da colheita.

INTRODUCTION

Harvesting bean seeds (*Phaseolus vulgaris* L.) at the right time is one of the factors that most contribute to high yield (Franco et al., 2013). To obtain a crop with high productive potential, it is necessary to value quality seed with high vigor and germination and maximum dry mass accumulation (Santos et al., 2005).

These characteristics are present, with greater evidence, in the physiological maturity of seeds, which is considered the ideal time for harvesting (Guimarães et al., 2012). According to Silva et al. (2009), the physiological maturity corresponds to the stage in which the plants present yellow leaves, with most of the pods dried and the seeds in their maximum development. However, at this stage, bean seeds have high water content and plants still have large numbers of leaves and green branches, making mechanized harvesting difficult (Coelho et al., 2007).

On the other hand, late harvests can expose the seeds to temperature and humidity fluctuations, as well as rain and adverse weather conditions, which causes several damages to the seeds. Increasing percentages of tegument cracking and wrinkling, easier pathogen penetration, and greater exposure of the embryonic tissue to the environment are factors related to climatic conditions, increasing the deterioration process and compromising its quality (Marcandalli et al., 2011), and may even culminate in total loss.

Because of this, it is necessary to use strategies that allow harvesting as soon as possible after the physiological maturity of the seeds. Veiga et al. (2007) report that the anticipation of harvest allows obtaining seeds of better physiological and sanitary quality. For Silva et al. (2009) and Daltro et al. (2010), one of the most widespread techniques is the application of desiccant herbicides, as it provides fast and uniform drying of plants, allowing earlier harvest.

Positive results were observed regarding the effectiveness of desiccants in reducing water content and preserving seed quality in soybeans (Kappes et al., 2009; Daltro et al., 2010) and beans (Kamikoga et al., 2009; Coelho et al., 2012).

However, before opting for the application of these products, one should be aware of the mode of action and the possibility of accumulation of residues in the seeds, which may compromise the physiological quality and even make them unviable for commercialization (Bulow and Silva, 2012). In this sense, several authors evaluated the use of herbicides for desiccation and found damage to seeds of soybean (Marcandalli et al., 2011; Botelho et al. 2016), beans (Kappes et al., 2012; Pinto et al., 2014) and wheat (Bellé et al., 2014).

Thus, studies are needed to minimize the detrimental effect of herbicides used as seed desiccants. One of the alternatives to minimize the negative effect of herbicides on seed quality is to reduce the dose in order to maintain their effectiveness and also to avoid waste, with consequent reduction of environmental contamination and production costs.

Another important factor, regarding the use of desiccants in pre-harvest of beans, is to define the best time for application of these herbicides, that is, applications after seed physiological maturity may compromise their quality or even their yield (Santos et al., 2005).

Thus, the use of different doses of herbicides applied at different times, after the physiological maturity of carioca beans, may affect seed quality and yield. Therefore, the objective of this work was to evaluate the physiological quality of carioca bean seeds, with the application of desiccant herbicide doses in two times, aiming to anticipate harvest.

MATERIAL AND METHODS

The research was conducted at the Universidade Federal da Fronteira Sul (UFFS), Campus Erechim. Sowing was carried out in the experimental area, and physiological analyzes were performed at the UFFS Laboratory of Sustainable Management of Agricultural Systems (MASSA).

The area used for bean sowing was previously desiccated with the glyphosate herbicide at a dose of 1,440 g ha^{-1}. The base fertilization, as well as the top-dressing, were made according to the physical and chemical analysis of the soil, following the technical recommendations for the bean crop (ROLAS, 2004).

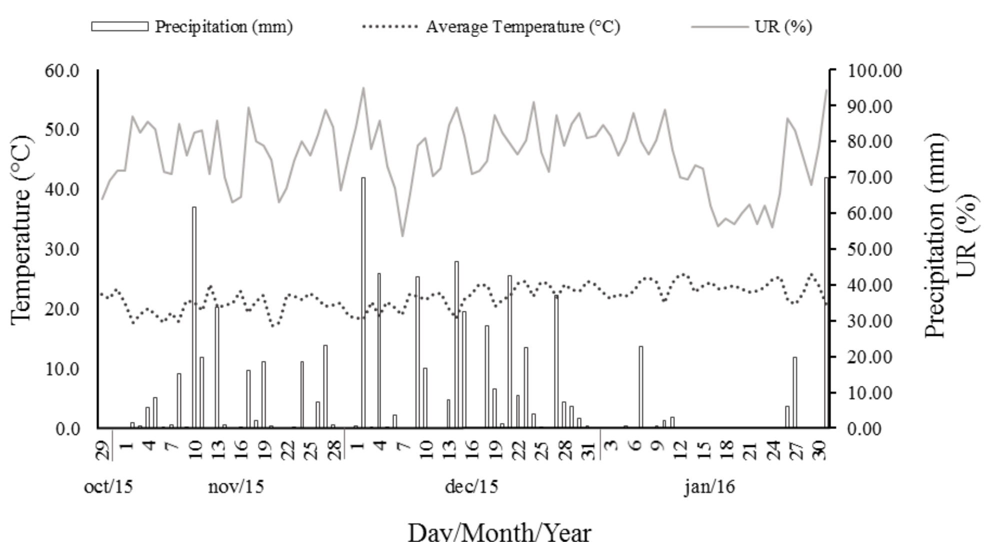
Sowing was done in a no-tillage system on 10/29/2015, using a six-row seeder/fertilizer, 0.50 m between rows. The sowing density of carioca bean, cultivar Pérola, was 14 viable seeds m^{-1}, totaling an estimated population of 280,000 plants ha^{-1}. Cultvation practices were carried out according to the technical information for bean cultivation for the southern Brazilian region (EPAGRI, 2012).

The average temperature, precipitation and relative humidity values recorded by INMET (2016) during the bean growing time are shown in Figure 1.

The experimental design was randomized blocks in a 2 x 3 x 4 factorial (application time x herbicide x dose), plus an additional treatment, with four replications. The desiccant application times were when the seeds had water content of approximately 42% and 30%, denominated, respectively, first and second times.

The maximum dose of each herbicide was 100% of the average commercial label dose recommended by the developers of Finale® (1.9 L ha^{-1}) - ammonium-glufosinate (380 g ha^{-1} a.i.), Heat® (105 g ha^{-1}) - saflufenacil (73.5 g ha^{-1} a.i.) and Reglone® (1,75 L ha^{-1}) - diquat (350 g ha^{-1} a.i.) for use in desiccations of beans for human consumption or for seeds (AGROFIT, 2017). Doses of 0%, 50%, 75% and 100% in relation to the recommended average dose of each product were applied to desiccate grains or seeds of beans for all herbicides (Table 1). The 0% dose was used as a control (without herbicide), as well as an additional treatment, without herbicide application, harvested with 18% water content, used to check the quality of conventionally produced seeds. The first time of application was determined by the weight of one thousand seeds, and the second time was defined based on the determination of water content of the seeds, performed by the stove method at 105 ± 3 °C (Brasil, 2009). The experimental unit (plot) consisted of an area of 15 m² (2.5 x 6.0 m).

The desiccant herbicides were applied with the aid of a precision CO_2 pressurized costal sprayer equipped with four DG 110.02 fan-type spray tips under constant pressure of 2.0 kgf cm^{-2} and a speed of 3.6 km h^{-1}, which generated a flow of 150 L ha^{-1} of volume application.



Fonte: INMET (2016)

Figure 1 - Weather conditions observed during the bean cultivation period, 2015/16 crop, in the municipality of Erechim/RS.

Table 1 - Specification of desiccant herbicides and their respective doses used for desiccation of carioca bean cultivar Pérola

Herbicide[1]	Recommended average dose		
	Active ingredient ($g\ ha^{-1}$)	Commercial product	Commercial dose (L ou $kg\ ha^{-1}$)
Amonio-glufosinate	380.0	Finale®	1.900
Saflufenacil	73.5	Heat®	0.105
Diquat	350.0	Reglone®	1.750

[1] Herbicides authorized by the Ministry of Agriculture, Livestock and Supply for desiccation of bean crop for human consumption or seeds (Brasil, 2017).

Harvesting of each experimental unit was performed manually, in a useful area of 11.0 m², disregarding a line on each side and 0.5 m of borders at the beginning and at the end of the experimental units. The control treatment (dose 0%) was harvested on the same date of application of the desiccants and subjected, still attached to the plant, to drying in stove with forced air circulation at 35 °C, until reaching water content close to 18%. Other treatments were harvested only when the seeds had approximately 18% water content in the field, regardless of the treatment.

After harvesting, the plants of each experimental unit were separately threshed, using a thresher for plots. The seeds of each repetition were then submitted to drying in a stove with forced air circulation and air temperature of 35 °C until reaching a water content of approximately 11%. These operations were the same for all treatments.

After drying was completed, the physiological quality of the seeds was determined by the following analyzes:

Germination: according to the criteria established by RAS (Brasil, 2009). The seeds were arranged in germinative paper rolls, moistened with water, in a proportion of 2.5 mass of dry paper, and then placed in a closed chamber germinator at 25 °C. The evaluation was made at nine days, computing the number of normal seedlings, and the results were expressed as percentage of germination.

First germination count: performed together with the germination test. On the fifth day after the test installation, normal seedlings were computed, and the results were expressed as a percentage (Brasil, 2009).

Germination speed index (GSI): performed according to the method described for the germination test, but only with seeds from the upper third of the paper. In this evaluation, only normal seedlings with at least 3 cm of shoot and root system were considered. The calculation of the IVG was performed according to the method proposed by Maguire (1962).

$$GSI = (G1/N1) + (G2/N2) + (G3/N3) + \dots + (Gn/Nn)$$, in which:

G1, G2, G3, ..., Gn = number of seedlings computed at first, second, third and last counts; and

N1, N2, N3, ..., Nn = number of days of sowing on first, second, third and last counts.

Cold test: 400 seeds were used for each treatment, which were distributed on previously moistened germinative paper, as described for the germination test. Then, the rolls were packed in sealed plastic bags and put in a refrigerator at 10 °C, where they remained for 72 h (ABRATES, 1999). Subsequently, the rolls were removed from the plastic bags and transferred to the germinator, set at 25 °C, where they remained for five days, when the evaluation was performed, computing the percentage of normal seedlings (Brasil, 2009).

Accelerated aging: 400 seeds were used per treatment, which were previously arranged in a single layer on a wire mesh, coupled to plastic boxes (gerbox), containing 40 mL of distilled water. The boxes were sealed and kept at 42 °C for 72 hours in a BOD germination chamber. After this period, the seeds were submitted to germination analysis and only normal seedlings were computed on the fifth day after the test installation. Results were expressed as percentage of normal seedlings (Marcos Filho, 1994).

Seedling and root length: carried out together with the germination speed index and according to the procedures described by Nakagawa (1999), adapted from AOSA (1983). To determine seedling length, the entire seedling was measured from the apical meristem to the base of the hypocotyl, and the measurements were made with the aid of a millimeter ruler. Root length was measured from the base of the hypocotyl to the end of the primary root. The average results were expressed in cm.

Dry mass transfer: Only the normal seedlings of each repetition from the germination speed index were considered. After removal of the cotyledons, the seedlings were placed in paper bags and kept in a greenhouse with forced air circulation, adjusted at 80 ± 2 °C for 24 hours. Afterwards, the samples were weighed in analytical balance, and the results were expressed in mg per seedling (Nakagawa, 1999).

Data were subjected to analysis of variance by the F test. Later, in case of significant effect, the qualitative variables were compared by Tukey and Dunnett tests ($p<0.05$), and the quantitative ones submitted to regression analysis, submitting the residues to normality analysis. The models were selected based on the significance of the parameters, applying the t test ($p\leq0.05$), on the significance of the mathematical model, by the value of "p", by the coefficient of determination (R^2) and by the biological adjustment. The means tests and regression analysis were performed using Assistat 7.7 and Sigma Plot 10.0 softwares, respectively.

RESULTS AND DISCUSSION

During the cycle of the carioca beans, the climatic conditions required for the crop were favorable (Figure 1). However, at the time of desiccant application and seed harvesting, there was a drought period, which contributed to the rapid drying of the plants in the field.

There was a significant interaction between application times, herbicides and doses for all evaluated response variables, except for root length, as shown in Table 2.

Table 2 - Summary of the analysis of variance, by F-test, of the means of the data for germination analysis (G), first germination count (FGC), germination speed index (GSI), cold test (CT), accelerated aging (AE), root length (RL), seedling length (SL) and dry mass (DM) and their coefficients of variation, obtained as a function of application time, herbicide type and doses

Source of variation	GL[6]	Value of p							
		G	FGC	GSI	CT	AA	RL	SL	DM
EP[1]	1	0.3790	<0.0001	<0.0001	0.0001	<0.0001	0.6185	<0.0001	0.1415
HB[2]	2	0.0017	0.0115	<0.0001	0.0050	0.0458	0.0155	0.0001	<0.0001
DS[3]	3	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EPxHB	2	<0.0001	<0.0001	<0.0001	<0.0001	0.0015	0.0921	0.0030	0.0042
EPxDS	3	0.4070	<0.0001	<0.0001	0.8310	0.0253	0.0102	0.4285	0.1136
HBxDS	6	0.1417	<0.0001	0.0075	0.0006	0.4430	0.2066	0.2438	0.0159
EPxHBxDS	6	0.0049	<0.0001	0.0002	<0.0001	0.0031	0.6482	0.0124	0.0094
T[4] x ADC[5]	1	<0.0001	0.0708	0.6161	0.6223	<0.0001	<0.0001	<0.0001	0.4088
CV (%)		2.79	2.36	2.91	2.95	3.03	4.00	3.98	4.88

[1] Application time; [2] Herbicide; [3] Dose. [4] Treatments. [5] Aditional. [6] Degrees of freedom.

For most responses, harvests performed when the seeds had 42% and 30% water content (exempt from desiccant application) were physiologically superior to the additional treatment harvested with 18% water (Table 3). This result corroborates literature, confirming that, the closer the seed is from physiological maturity, the better the seed quality (Mathias et al., 2017).

Figure 2 shows the results of germination (A), first germination count (B) and germination speed index (C). There was a reduction in the germination percentage, in the first count and in the GSI due to increasing doses at both application times and for the three evaluated herbicides. However, when observing the GSI, it can be observed that it showed the highest decrease, between 0% and 50% of the recommended average dose, remaining then practically stable with the dose increase for the three herbicides and both application times.

Table 3 - Results obtained by Dunett test (p≤0.05) for the variables germination (G), first germination count (FGC), germination speed index (GSI), cold test (CT), accelerated aging (AE), root length (RL), seedling length (SL) and dry mass (DM), obtained as a function of application time, herbicide type and doses, compared to additional treatment

Treatment			Average							
EP(1)	HB(2)	DS(3)	G	FGC	GSI	CT	AA	RL	SL	DM
1	Control	0	97.00**	91.67**	24.87**	91.75**	94.75**	14.02	11.64*	0.0483**
1	1	50	92.75**	85.50	23.00	84.75	80.25	13.49*	10.82*	0.0389
1	1	75	88.75**	83.34	23.32**	81.75	77.00	13.24*	9.61*	0.0392
1	1	100	88.00	82.39	22.75	81.50	78.00	12.35*	9.58*	0.0348*
1	2	50	90.50**	86.11	22.24	87.50**	81.25	12.89*	10.59*	0.0468**
1	2	75	88.75**	74.67*	22.01*	80.25	79.50	12.43*	10.14*	0.0421
1	2	100	81.25	69.89*	21.56*	73.08*	78.00	12.07*	9.55*	0.0356*
1	3	50	86.00	83.12	21.25*	77.25	80.75	12.62*	9.44*	0.0382
1	3	75	86.50	81.67*	21.43*	72.50*	79.00	12.04*	9.30*	0.0381
1	3	100	82.75	72.34*	20.93*	72.50*	75.25	11.86*	9.30*	0.0356*
2	Control	0	96.00**	90.00	26.40**	89.25**	96.75**	14.31	12.00*	0.0483**
2	1	50	88.17	84.22	22.05*	79.50	86.25**	13.58*	10.19*	0.0382
2	1	75	86.00	82.50	21.02*	72.25*	81.75	12.92*	10.03*	0.0381
2	1	100	8200	81.00	21.42*	72.08*	73.25	11.45*	9.95*	0.0356*
2	2	50	92.00**	86.52	23.45**	81.25	82.00	13.56*	11.07*	0.0418
2	2	75	90.50**	85.37	22.61	73.33*	80.25	12.11*	10.73*	0.0411
2	2	100	87.00	83.67	23.78**	72.00*	74.75	11.45*	10.70*	0.0393
2	3	50	91.50**	85.22	22.40	80.00	86.75**	13.16*	10.93*	0.0430
2	3	75	85.50	85.00	22.11*	79.25	82.75**	12.76*	10.21*	0.0409
2	3	100	88.00	80.89*	22.47	75.33*	82.75**	11.77*	9.96*	0.0382
Additional			83.00	86.00	22.75	81.33	77.25	14.77	13.01	0.0424

* and ** Means lower and higher than the additional treatment, respectively. (1) Application times 1 and 2: (42% e 30% of water content, respectively); (2) Herbicides: (1: ammonium-glufosinate, 2: saflufenacil, 3: diquat); (3) Percentage doses in relation to the recommended average dose for each product.

The germination percentages of seeds from treatments without herbicide application were higher than the additional treatment in both times. This result confirms that seeds harvested close to physiological maturity present higher germination percentage compared to seeds harvested with water content close to 18% (additional). However, there was no difference between additional treatment and desiccations using 100% of the dose for the three herbicides at both times. On the other hand, the application of the herbicide saflufenacil in the first and second times, up to 75% dose, provided a higher germination percentage than the additional treatment, while ammonium-glufosinate only showed better response in the first time. On the other hand, the herbicide diquat did not provide better response to germination percentage compared to the additional treatment, except for the 50% dose when applied in the second time (Table 3).

Guimarães et al. (2012), using the herbicide ammonium-glufosinate at a dose of 400 g ha^{-1} (100% of the recommended dose) for soybean seed desiccation, noted a 12.3% reduction in germination compared to the control (no desiccation, harvested when the plants were visually dry).

Ammonium-glufosinate, at the doses tested, caused greater damage to seed germination when applied late, that is, when bean seeds had water content of 30% (Figure 2A), but showed little difference compared to other herbicides applied at the same time, being only 6.36% and 4.73% higher in relation to saflufenacil and diquat, respectively, in the highest dose. Lamego et al. (2013), in studies with soybean seeds, also noticed a reduction in germination percentage in later desiccations. Pinto et al. (2014) found a smaller amount of normal seedlings in the germination test when using the herbicide ammonio-glufosinate for bean desiccation. Domingos et al. (1997) observed reduction in germination and vigor when this same herbicide was applied to carioca bean seeds with water content between 37% and 42%, using the dose of 400 g ha^{-1}.

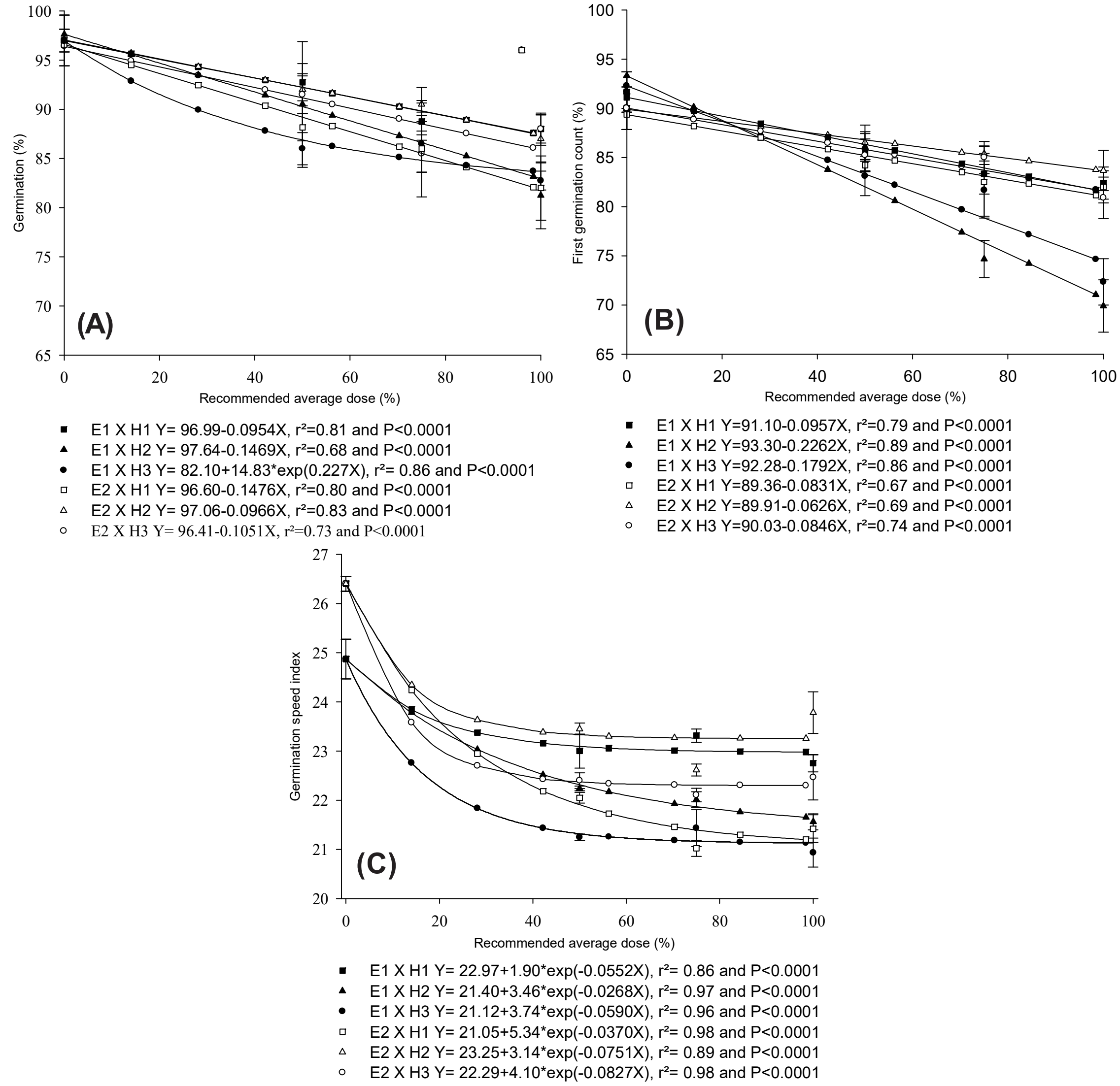


Figure 2 - Germination (A), first germination count (B) and germination speed index (C) of carioca bean seeds, as a function of the application of percentage doses in relation to the recommended average of desiccant herbicides (H1: ammonium glufosinate; H2: saflufenacil; H3: diquat) at times E1 and E2, respectively, with 42% and 30% of water in the seeds. UFFS, Erechim, 2016.

Unlike amonium-glufosinate, the herbicides saflufenacil and diquat showed lower germination percentages at all doses in the first time desiccations. Although the difference is small, it is supposed to occur because the seed in the first time is still linked to the original plant, causing higher product absorption. Domingos et al. (1997) point out that this situation occurs due to the probable ease of translocation of the herbicide to the seed, provided by high humidity levels. The same authors also report that, in terms of physiological seed quality, ammonium glufosinate is inadequate for desiccation of carioca bean seeds, as they observed a considerable percentage of milky white embryos in the tetrazolium test, which can be associated with the lethal effect of ammonium glufosinate on the seed.

Mata et al. (2015) found differences in germination percentages among eight bean cultivars, using different herbicides in pre-harvest desiccation, among them diquat, saflufenacil and ammonio-glufosinate. Comparisons between herbicides showed lower germination percentages when ammonium-glufosinate was used, followed by saflufenacil and diquat.

In general, the lowest percentages of germination occurred in the highest tested doses, with an average decrease of 12.45% in relation to the 0% dose for both times and applied products, but still with values above the minimum recommended for commercialization of bean seeds, which must be at least 80% (Brasil, 2013).

The lowest percentages of normal seedlings germinated at the first germination count occurred when the highest dose was applied, as opposed to the non-desiccated plants (0% dose) harvested at the same date of application, which presented the highest percentages. This occurred for all three herbicides and for both application times (Figure 2B). The control treatment (0% dose) was also superior to the additional treatment (harvested at the end of the experiment) in the first time (42% of water), not differing from this in the second time (30% of water) (Table 3). Souza (2009) observed that glyphosate doses higher than 1.5 L ha^{-1} reduced the percentage of normal seedlings at the first germination count in the three evaluated cultivars. Similarly, Kappes et al. (2009) found a higher germination percentage in seeds from non-desiccated soybean plants (harvested together with the other treatments), compared with desiccations performed with the herbicides diquat and paraquat.

There was a linear reduction in the germination percentage in the first count with increasing doses. The herbicides saflufenacil and diquat caused a higher reduction of normal seedlings in the first count when applied in the first time (42% of water), as opposed to the second time (30% of water), with a 15.5% difference between times for saflufenacil and 8.8% for diquat. On the other hand, the herbicide ammonium-glufosinate showed similar results in both times, with a reduction of only 0.6% in the second time (Figure 2B). There was no difference in the application of ammonium-glufosinate in relation to the additional (harvested with 18% water) at 50%, 75% and 100% doses compared to the recommended average dose of this herbicide (1.9 L ha^{-1}), regardless of the time of application (Table 3).

Pinto et al. (2014) observed that ammonium-glufosinate reduces the number of normal bean seedlings, compared to the control treatment (without desiccant application, harvested together with the other treatments), for all application times. Tavares et al. (2015) found a linear reduction in the percentage of normal bean seedlings in the first count, with increasing doses of the herbicide saflufenacil, in the evaluations performed after harvest, corroborating the results of the present study. However, Franco et al. (2013) did not verify the effect of diquat, using different application stages, in the first germination count evaluations of carioca beans, cultivar Pérola.

Control treatments (0% dose) produced more vigorous seeds compared to the use of all herbicides at 50%, 75% and 100% doses. In this condition (0% dose), GSI was higher for time 2 by 5.8% (Figure 2C). The control treatment (0% dose) was also superior to the additional treatment (exempt from desiccant application and collected with 18% water), in both times (Figure 3).

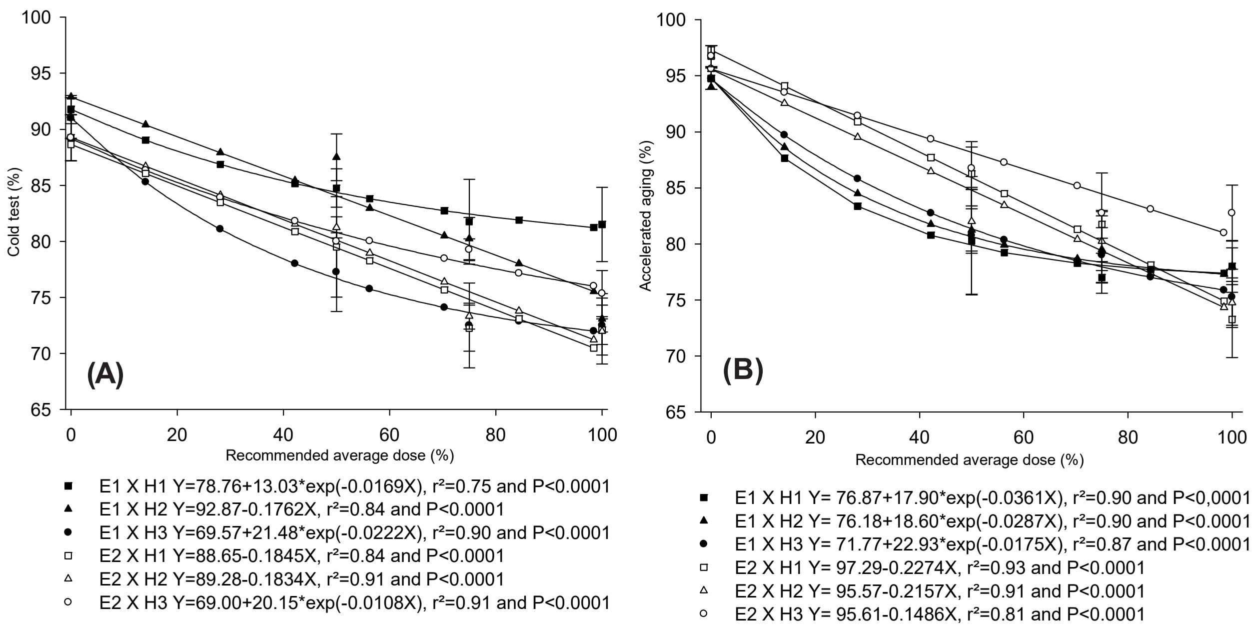


Figure 3 - Germination of carioca bean seeds submitted to the cold test (A) and accelerated aging (B), as a funtion of the application of percentage doses in relation to the recommended average of desiccant herbicides (H1: ammonium-glufosinate; H2: saflufenacil; H3 : diquat) at times E1 and E2, respectively, with 42% and 30% of water in the seeds. UFFS, Erechim, 2016.

From the 50% dose, in both times and herbicides, GSI showed little reduction (Figure 2C). The lowest indexes occurred when diquat and ammonium-glufosinate were applied at the first and second times, respectively, at the three evaluated doses. These results disagree with Franco et al. (2013), who observed lower GSI when bean plants received diquat desiccant application at a later time.

Figure 3 shows the results of germination percentages from the cold test (A) and accelerated aging (B). In both tests, there was a reduction in germination percentage with increasing doses for both application times and types of herbicides applied.

The results show a reduction in germination percentage with increasing doses when the seeds were subjected to the cold test (Figure 3A), compared to the germination analysis (Figure 2A), for all times and herbicides tested. This is due to the fact that the seeds have lower physiological quality due to increased doses; thus, the degradation is increased, causing lower germination percentages.

Again, the application of ammonium-glufosinate in the second time damaged bean seeds (Figure 3A), with a 23.5% reduction in cold test germination compared to the first time at the highest dose. In addition, the application of this herbicide caused a decrease of 14.2% and 20.8% in germination, respectively, with increasing doses at both times. The herbicide saflufenacil presented similar behavior to that of ammonium-glufosinate when applied in the second time, with a difference of only 1% between both for the highest dose.

The worst seed germination results, when subjected to the cold test (Figure 3A), were caused by diquat applications in the first time. However, at the highest dose (100% of the recommended average dose) the herbicides ammonium-glufosinate and saflufenacil, applied in the second time, presented similar germination percentage. It is also noted that its behavior was similar to that shown for GSI (Figure 2C).

The seeds from the control treatment (dose 0%) presented higher germination percentage when submitted to the cold test, compared to those submitted to the herbicide application (doses of 50%, 75% and 100%) (Figure 3A) for both times and herbicides.

These results show that bean seeds submitted to cold test have low physiological quality when plants are desiccated with the highest herbicide doses, for both times, because the germination percentage is less than 80%, except when ammonium-glufosinate is applied in the first time. Similar results were obtained in studies by Kappes et al. (2012), using paraquat in desiccation of carioca bean seeds. However, when 50% of the recommended average dose was used, it should be noted that for the first time only diquat led to a germination percentage below 80% (Figure 2C).

Similar to the cold test (Figure 3A), there was a decrease in germination percentage due to increased herbicide doses at both times when the seeds were submitted to the accelerated aging test (Figure 3B). In the absence of herbicide application (0% dose), again, the highest germination percentages were obtained, being, on average, 19.73% higher in relation to the 100% dose and also higher than the additional (without desiccation, harvested with 18% water) for both times (Table 3).

Inoue et al. (2003) observed a reduction in vigor of soybean seeds submitted to accelerated aging test when the herbicides diquat, paraquat, carfentrazone-ethyl and ammonium-glufosinate were applied. However, in the latter, the reduction in germination was less pronounced, with values close to those obtained with the control (without desiccant application, harvested with 95% of mature pods).

There was also a reduction in the germination percentage for accelerated aging compared to the germination test (Figure 2A). These results corroborate those obtained by Coelho et al. (2012), who, studying the action of paraquat as a desiccant at different times, in the pre-harvest of creole bean seeds, found a marked decrease in germination percentage due to the stress caused by the accelerated aging test compared to not-aged seeds.

The applications performed in the first time caused lower vigor in the three herbicides used for most doses tested, except for 100%, but with an average difference of only 3.26% in relation to the herbicides ammonium-glufosinate and saflufenacil applied in the second time. Kamikoga et al. (2009) found that glyphosate is more detrimental to the germination of black-beans if applied when the seed has high water content and reported that water may be the transport agent of the desiccant to the inner tissues of the seed.

Figure 4 presents the results of root length analysis as a function of times (Figure 4A) and doses (Figure 4B).

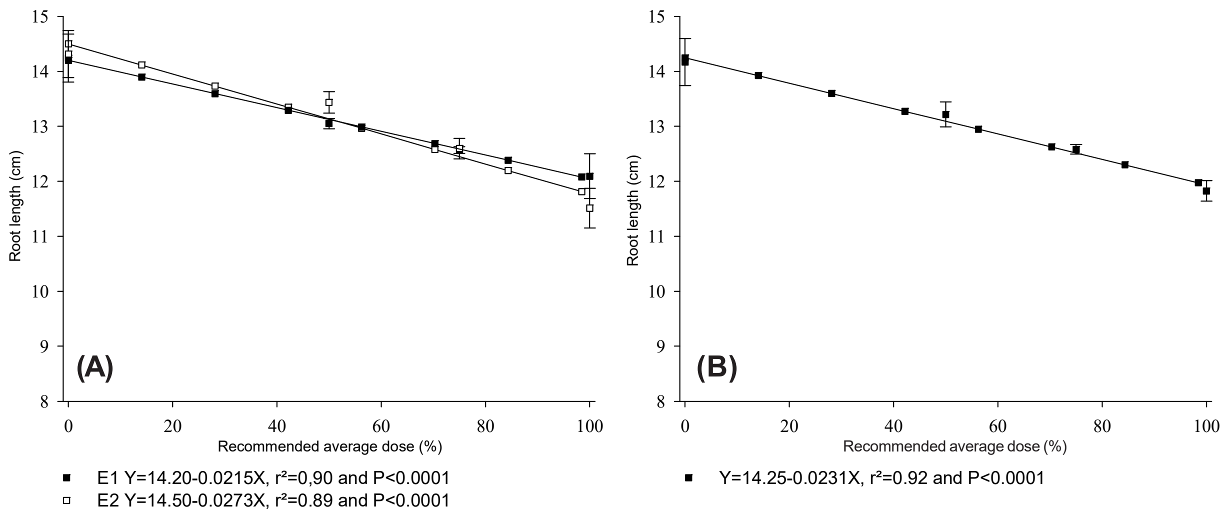


Figure 4 - Root length of carioca bean seedlings as a function of the application of different percentage doses, in relation to the recommended average of desiccant herbicides (H1: ammonium-glufosinate; H2: saflufenacil; H3: diquat) at times E1 and E2, respectively, with 42% and 30% of water in the seeds. UFFS, Erechim, 2016.

At both times (Figure 4A) there was a reduction in root length as doses were increased, regardless of the evaluated herbicide. It can be seen that the desiccation performed in the second time was more detrimental to the root length with the increase of doses, compared to the first time, however this difference was only 2.3%. As shown in Figure 4B, root length decreased when plants were desiccated at higher doses for the three herbicides at both application times.

Using the herbicide diquat in soybeans, Inoue et al. (2012) showed greater root length in desiccation of plants that had higher number of yellow pods, that is, in later applications. Daltro et al. (2010) and Toledo et al. (2012) found that the use of glyphosate in desiccation causes phytotoxic effects and lower development of soybean seedling roots.

The root length was longer when ammonium-glufosinate was applied compared to the other herbicides, regardless of the dose and time of application, but showing a difference of only 2.3% and 2.6% for saflufenacil and diquat, respectively. (Table 4). Tarumoto et al. (2015), using ammonium-glufosinate, glyphosate and paraquat in pre-harvest desiccation in wheat, did not find significant difference for root length, differing from the results found in the present study.

However, it was found that, despite expressing little superiority among the other herbicides, ammonium glufosinate still presented results that were inferior to the additional treatment, with average root length of 14.8 cm (Table 3), 10.83% higher than found for the ammonium glufosinate herbicide (Table 4).

There was a linear decrease in seedling length with increasing doses for the three herbicides tested at both application times, with an average reduction of 17% for the highest dose (Figure 5A). The highest seedling length values were observed when there was no desiccation (0% dose) for both times. However, this same treatment presented shorter seedling length than that obtained in the additional treatment (Table 3). Toledo et al. (2012) also found a reduction in soybean seedling development due to glyphosate utilization, compared to the absence of desiccation, regardless of the time of application. However, Daltro et al. (2010), using diquat in the pre-harvest desiccation of two soybean cultivars, found that there was no significant difference in seedling length in relation to the control (without desiccant application).

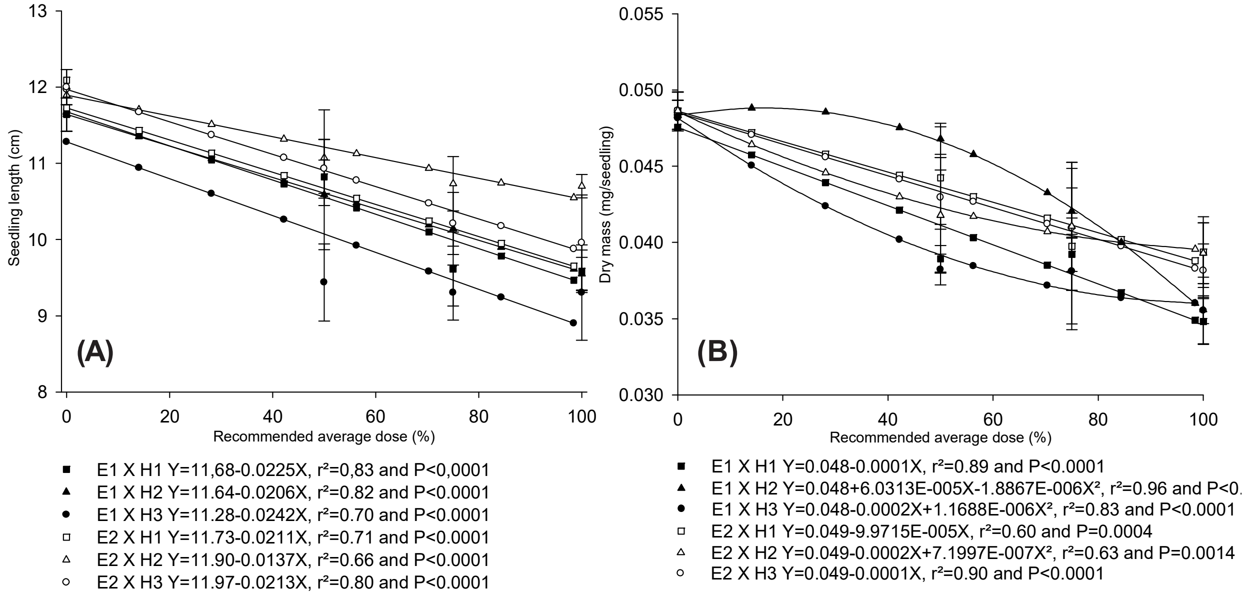


Figure 5 - Seedling length (A) and dry matter transfer (B) of bean seedlings, as a function of percentage doses in relation to the recommended average of desiccant herbicides (H1: ammonium-glufosinate; H2: saflufenacil; H3: diquat) at E1 times and E2, respectively, with 42% and 30% of water in the seeds. UFFS, Erechim, 2016.

Second time applications provided the highest seedling lengths for all herbicides compared to the first time. Diquat applied in the first time was responsible for the shorter seedling lengths in all doses tested, being 10% lower than in the second time. The results in the present study corroborate those obtained by Toledo et al. (2012), who found that later application of glyphosate causes longer soybean seedlings.

Table 4 - Root length (cm) of carioca bean seedlings as a function of the application of the recommended average dose of desiccant herbicides (ammonium-glufosinate; H2: saflufenacil; H3: diquat). UFFS, Erechim, 2016

Herbicide	Root length (cm)
Amonio-glufosinate	13.17 a
Saflufenacil	12.86 b
Diquat	12.82 b
CV (%)	4.00

Means followed by the same letter in column are not different by Tukey test at a 5% probability level.

When the seeds had 42% of water, the application of the highest dose of herbicides resulted in less dry mass transfer, which were considered less vigorous (Figure 5B). This result agrees with that presented by Lamego et al. (2013), who, in pre-harvest desiccation of soybean, found that seedlings from desiccation at the R6 stage (pods with grains and 100% green leaves) showed lower dry weight.

Again, the diquat applied in the first time caused the lowest dry mass transfer values (Figure 5B). This result may be due to the shorter seedling and root lengths found for this herbicide (Figure 5A and Table 4). In this case, it is suggested that diquat, linked to excess moisture, may have been absorbed by the seeds. Thus, there was a delay in their emergence, which led to shorter seedling and root lengths and, consequently, lower dry mass, on the ninth day, after being submitted to germination.

In general, pre-harvest desiccation of beans using the commercial dose of the herbicides amonium-glufosinate, diquat and saflufenacil impairs the physiological quality of the seeds. Harvesting bean seeds with 30% and 42% water content, without the use of desiccants, promotes high vigor and germination. The most appropriate time to desiccate carioca beans, cultivar Pérola, is when the seeds have a water content of around 30%, using the herbicide saflufenacil at a dose of 50% (36.75 g ha^{-1} a.i.) compared to the average dose recommended by the manufacturer (73.5 g ha^{-1} a.i.).

REFERENCES

Associação Brasileira de Tecnologia de Sementes – ABRATES. Londrina: Comitê de Vigor de Sementes, ABRATES; 1999. 218p.

Association of Official Seed Analysts – AOSA. Seed vigor testing handbook. East Lansing: AOSA; 1983. 93p. (Contribution, 32).

Bellé C, Kulczynski SM, Basso CJ, Kaspary TE, Lamego FP, Pinto MAB. Yield and quality of wheat seeds as a function of dessication stages and herbicides. J Seed Sci. 2014;36:63-70.

Botelho FJE, Oliveira JA, Von Pinho ÉVR, Carvalho ER, Figueiredo ÍBD, Andrade V. Qualidade de sementes de soja obtidas de diferentes cultivares submetidas à dessecação com diferentes herbicidas e épocas de aplicação. Rev Agro@mbiente. 2016;10:137-44.

Brasil. Ministério da Agricultura e Pecuária e Abastecimento. AGROFIT. 2017[acessado em: 20 de ago. 2017]. Disponível em: http://www.agricultura.gov.br.

Brasil. Ministério da Agricultura, Pecuária e Abastecimento. Instrução Normativa nº 45 de 17 de set de 2013. Anexo XI - Padrões para produção e comercialização de sementes de feijão (Phaseolus vulgaris L.). Brasília, DF: Secretaria de Defesa Agropecuária; 2013.

Brasil. Ministério da Agricultura, Pecuária e Abastecimento. Regras para análise de sementes. Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Defesa Agropecuária. Brasília DF: MAPA/ACS; 2009. 395p.

Bulow RL, Silva CTAC. Dessecantes aplicados na pré-colheita na qualidade fisiológica de sementes de soja. J Agron Sci. 2012;1:67-75.

Coelho CMM, Souza CA, Zilio M, Michels AF. Ação de dessecante na pré-colheita sobre a produtividade e a qualidade fisiológica de sementes crioulas de feijoeiro. Semina: Cienc Agr. 2012;33:2973-80.

Coelho C.M.M. et al. Diversidade genética em acessos de feijão (*Phaseolus vulgaris* L.) Cienc. Rural. 2007;37:1241-7.

Daltro EMF, Albuquerque MCF, França Neto JB, Guimarães SC, Piza Gazziero DL, Henning AA. Aplicação de dessecantes em pré-colheita: Efeito na qualidade fisiológica de sementes de soja. Rev Bras Sementes. 2010;32:111-22.

Domingos M, Silva AA, Silva RF. Qualidade da semente de feijão afetada por dessecantes, em quatro estádios de aplicação. Rev Bras Sementes. 1997;19:276-83.

EPAGRI – Comissão Técnica Sul-Brasileira de Feijão. Informações técnicas para o cultivo do feijão na região Sul-Brasileira. 2012. 2ª.ed. Florianópolis: 2012. 157p.

Franco MHR, Nery MC, França AC, Oliveira MC. Produção e qualidade fisiológica de semente de feijão após aplicação do herbicida diquat. Semina: Cienc Agr. 2013;34:1707-14.

Guimarães VF, Hollmann MJ, Fioreze SL, Echer MM, Rodrigues-Costa ACP, Andreotti, M. Produtividade e qualidade de sementes de soja em função de estádios de dessecação e herbicidas. Planta Daninha. 2012;30: 567-73.

Inoue MH, Xavier PPS, Mendes KF, Ben R, Dallacort R, Mainardi JT, Araújo DV, Conciani PA. Determinação do estádio de dessecação em soja de hábito de crescimento indeterminado no Mato Grosso. Rev Bras Herb. 2012;11:71-83.

Inoue MH, Marchiori Júnior O, Braccini AL, Oliveira Júnior RS, Ávila MR, Constantin J. Rendimento de grãos e qualidade de sementes de soja após a aplicação de herbicidas dessecantes. Cienc Rural. 2003;33:769-70.

Instituto Nacional de Meteorologia – INMET. Normais Climatológicas do Brasil 1961-1990: Precipitação Acumulada Mensal e Anual (mm), Estação Passo Fundo. [acessado em: 15 dez. 2016]. Disponível em: http://www.inmet.gov.br/portal/index.php?r=clima/normaisClimatologicas

Kamikoga ATM, Kamikoga MK, Terasawa JM, Romanek C, Penkal KF. Efeito de diferentes épocas de aplicação de três herbicidas dessecantes na produção e qualidade fisiológica de sementes de feijão. Cienc Exatas Terra Cienc Agr Eng. 2009;15:53-61.

Kappes C, Arf O, Ferreira JP, Portugal JR, Alcalde AM, Arf MV, Vilela RG. Qualidade fisiológica de sementes e crescimento de plântulas de feijoeiro, em função de aplicações de paraquat em pré-colheita. Pesq Agropec Trop. 2012;42:9-18.

Kappes C, Carvalho MAC, Yamashita OM. Potencial fisiológico de sementes de soja dessecadas com diquat e paraquat. Sci Agríc. 2009;10:1-6.

Lamego FP, Gallon M, Basso CJ, Kulczynski SM, Ruchel Q, Kaspary TE, Santi AL. Dessecação pré-colheita e efeitos sobre a produtividade e qualidade fisiológica de sementes de soja. Planta Daninha. 2013;31:929-38.

Maguire JD. Speed of germination aid in selection and evaluation for seedling and vigor. Crop Sci. 1962;2:176-7.

Marcandalli LH, Lazarini E, Malaspina IC. Épocas de aplicação de dessecantes na cultura da soja: qualidade fisiológica de sementes. Rev Bras Sementes. 2011;33:241-50.

Marcos Filho J. Teste de envelhecimento acelerado. In: Carvalho NM, Vieira RD. Testes de vigor em sementes. Jaboticabal: FUNEP; 1994. p.133-49.

Mata DC. Dessecação pré-colheita de cultivares de feijoeiro-comum com diferentes princípios ativos [dissertação]. Lavras: Universidade Federal de Lavras; 2015.

Mathias V, Pereira T, Mantovani A, Zílio M, Miotto P, Coelho CMM. Implicações da época de colheita sobre a qualidade fisiológica de sementes de soja. Rev Agr@ambiente On-line. 2017;11:223-31.

Nakagawa J. Testes de vigor baseados na avaliação das plântulas. In: Vieira RD, Carvalho NM. Testes de vigor em sementes. Jaboticabal: FUNEP; 1999. p.49-85.

Pinto MAB, Basso CJ, Kulczynski SM, Bellé C. Productivity and physiological quality of seeds with burn down herbicides at the pre-harvest of bean crops. J Seed Sci. 2014;36:384-91.

Rede Oficial de Laboratórios de Análise de Solo e de Tecido Vegetal – ROLAS. Manual de adubação e calagem para os estados do Rio Grande do Sul e Santa Catarina. 10ªed. Porto Alegre: Sociedade Brasileira de Ciência do Solo; 2004. 400p.

Santos JB, Ferreira EA, Ferreira EM, Silva AA, Ferreira LR. Efeitos da dessecação de plantas de feijão sobre a qualidade de sementes armazenadas. Planta Daninha. 2005;23:645-51.

Silva JG, Aidar H, Kluthcouski J. Colheita direta de feijão com colhedora automotriz axial. Pesq Agropec Trop. 2009;39:371-9.

Souza FLG. Dessecação com glyphosate em pré-colheita e qualidade fisiológica de sementes de soja [dissertação]. Botucatu: Universidade Estadual Paulista, Faculdade de Ciências Agronômicas; 2009.

Tarumoto MB, Carvalho FT, Arf O, Silva PHF, Pereira JC, Bortolheiro FPAP. Dessecação em pré-colheita no potencial fisiológico de Sementes e desenvolvimento inicial de trigo. Cult Agron. 2015;24:369-80.

Tavares CJ, Araújo ACF, Jakelaitis A, Resende O. Qualidade de sementes de feijão-azuki dessecadas com saflufenacil e submetidas ao armazenamento. Rev Bras Eng Agríc Amb. 2015;19:1197-202.

Toledo MZ, Cavariani C, França-Neto JB. Qualidade fisiológica de sementes de soja colhidas em duas épocas após dessecação com glyphosate. Rev Bras Sementes. 2012;34:134-42.

Veiga AD, Rosa SDVF, Silva PA, Oliveira JÁ, Alvim PO, Diniz KA. Tolerância de sementes de soja à dessecação. Ciênc Agrotec. 2007;31:773-80.