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# Effects of desiccation with glyphosate on two common bean cultivars: physiology and cooking quality of the harvested product

**Mariana Casari Parreira[1], Leandro Borges Lemos[2], João Portugal[3] and Pedro Luis da Costa Aguiar Alves[4*]**

**[1]College of Agricultural (FAGRO), CUNTINS-UFPA CEP 68400-000, Cametá, PA, Brazil**
**[2]Department of Plant Production - FCAV-UNESP, CEP 14844-900, Jaboticabal, SP, Brazil**
**[3]Department of Biosciences - ESA- IPBeja, CP 7800-295, Beja, Portugal**
**[4]Department of Applied Biology - FCAV-UNESP, CEP 14844-900, Jaboticabal, SP, Brazil**

***Corresponding author: plalves@fcav.unesp.br**

**Abstract**

The aim of this work was **to** evaluate the effect of glyphosate when used on two bean cultivars for the desiccation of weeds during the pre-harvest period and the consequences on the physiologic characteristics and cooking quality of the harvested product. Treatments consisted of four doses of glyphosate used as a desiccant: 180, 360, 720, and 1,080 g a.i. $ha^{-1}$, ammonium gluphosinate at 360 g a.i. $ha^{-1}$, as well as a control without application of desiccant, applied to two bean cultivars (Pérola and IPR Juriti). For each of the cultivars, the experimental design was a completely randomized design with five replicates. The desiccants were applied during phenological stage R9 of the crop (maturation), which occurred 74 days after sowing (DAS). The harvest was performed 13 days after application (87 DAS). The treatments did not affect productivity, 100-bean weight, electric conductivity, accelerated aging, cooking time, or bean hydration. However, higher glyphosate doses negatively affected first count value, index of emergence speed, and seedling dry mass. The use of the herbicide glyphosate up to a rate of 1,080 g a.e. $ha^{-1}$ as a desiccant against weeds in the pre-harvest period is possible for the bean market. However, if the harvested product is destined for the planting of a new crop, caution should be observed with the use of this herbicide.

**Keywords:** beans; herbicide; *Phaseolus vulgaris*; seed; grain.
**Abbreviations:** a.e. – acid equivalent; a.i. – active ingredient; DAS – days after sowing; FCV – first count value; HR – hydration ratios; IGS – index of germination speed; MHT – maximum hydration times.

## Introduction

Bean plants belong to the genus *Phaseolus*, which includes approximately 55 species, of which five are cultivated: *P. vulgaris* L., *P. lunatus* L., *P. coccineus* L., *P. acutifolius* A. Gray var. *latifolius* Freman, and *P. polyanthus* Greenman. Among these, the common bean (*Phaseolus vulgaris*) is the most important because it is the oldest cultivated species and the most widely grown species on five continents (EMBRAPA, 2013). Bean cultivation, which was historically practiced almost exclusively by small producers, has more recently been conducted in larger areas by producers that employ advanced technology and are able to achieve high productivity (Kappes et al., 2012). Due to the mostly indeterminate growth of beans and the direct and indirect interference of weeds during their harvest (Barroso et al., 2012), the use of desiccants has increased. In addition to minimizing interference by weeds, pre-harvest desiccation reduces the weed seed bank and offers a higher-quality harvested product by facilitating the harvest (Daltro et al., 2010; EMBRAPA, 2013), assisting in harvest planning (Veiga et al., 2007), and preserving seed productivity and quality (Lacerda et al., 2005). The pre-harvest use of desiccants to produce seeds does not hinder germination when performed by physiological maturity and can, in some cases, even improve germination (Domingos et al., 2000). However, other studies have found negative effects of the adoption of this practice on seed quality (Moyer et al., 1996).

In addition to the physiological quality of the seeds, the cooking quality is another crucial factor to consider when using desiccants pre-harvest because beans are a staple for many people. Therefore, it is important that the desiccant performs its role without modifying the cooking and/or technological characteristics desired by consumers, i.e., short cooking time, high hydration capacity, quantity, and protein quality (Carbonell et al., 2003). Various products have been recommended for the desiccation of different crops (May et al., 2003). Yet, few registered products have been recommended for beans (Wilson and Smith, 2002), and the most widely utilized product (ammonium glufosinate) is costly, which leaves the producer with little room for choice.

Glyphosate is an herbicide derived from the amino acid glycine, and its mechanism of action is the inhibition of 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS), the enzyme responsible for one of the steps involved in the synthesis of the aromatic amino acids tryptophan, phenylalanine, and tyrosine (Zonetti et al., 2011; Duke et al., 2012). Glyphosate is not selective, except in the case of cultivars genetically modified for resistance, and it is systemic (Moldes et al., 2012). Glyphosate can be used to control annual and perennial weeds, for desiccation, especially in areas of direct planting, and for weed management in perennial crops, and when used at recommended doses, glyphosate is not toxic to plants in the soil (Bohm et al., 2014). Glyphosate has also been successfully used to mature sugarcane (Dalley and Richard, 2010), rapeseed (Mitsis et al., 2011), flax (Sampaio et al., 2005), and alfalfa (May et al., 2003). The hypothesis of this study is that the herbicide glyphosate can be used as a desiccant against weeds in the pre-harvest stage of bean crops without affecting the physiological quality of the seeds or the cooking quality of the beans. Thus, the objective of this study was to evaluate the effect of doses of the herbicide glyphosate applied for the desiccation of weeds during pre-harvest on two bean cultivars and to assess the physiological characteristics and cooking quality of the harvested product.

## Results

The doses of glyphosate and ammonium glufosinate did not have an effect on the productivity and 100-bean weight analyses of the two bean cultivars (Table 1).

### *Physiological quality of the seeds*

The germination test revealed a difference in the first count value (FCV; Table 2). As the dose of glyphosate increased, the FCV decreased; the doses of 720 and 1080 g a.e.ha$^{-1}$ resulted in FCVs of only 32.5% and 11% for the Pérola cultivar, respectively, and 43% and 20.5% for the IPR Juriti cultivar, respectively, while the standard desiccant (ammonium glufosinate) reduced the FCV by an average of 11%. For the Juriti cultivar, the impact of glyphosate on reducing FCV was significant beginning at 360 g a.e.ha$^{-1}$. The index of germination speed (IGS) demonstrated the same pattern as that of FCV but with a significant effect at doses of 360 g a.e.ha$^{-1}$ and above for both of the cultivars, with a more accentuated effect at higher doses. In contrast, IGS was not affected by ammonium glufosinate. At the end of the germination test, the percentage of germinated seeds was extremely high and varied from 97 to 100% for all glyphosate doses for both of the cultivars tested. There was no significant effect of this product, similar to the results for ammonium glufosinate. The shoot dry mass of the two cultivars was not affected by the desiccants (Table 3) and varied from 0.126 to 0.165 g plant$^{-1}$ for the Pérola cultivar and from 0.129 to 0.160 g plant$^{-1}$ for the IPR Juriti cultivar. However, the root dry mass of the seedlings was reduced by the treatments. For the Pérola cultivar, an impact of glyphosate on reducing root dry mass was observed beginning at the dose of 360 g a.e.ha$^{-1}$, and this effect was more accentuated at the higher doses of glyphosate (720 and 1080 g a.e.ha$^{-1}$). In contrast, ammonium glufosinate did not affect root dry mass. For the Juriti cultivar, all of the doses of glyphosate and of ammonium glufosinate reduced the root dry mass of the seedlings. This effect was again greatest at the two highest doses of glyphosate, which caused more than 70% reduction in the root dry mass of the two cultivars. There were no differences among the treatments in the electric conductivity for both bean cultivars (Table 4). However, the Pérola cultivar had higher electric conductivity values, which fluctuated between 62 and 70 µS cm$^{-1}$ g$^{-1}$, while the values for the IPR Juriti cultivar varied between 41 and 49 µS cm$^{-1}$ g$^{-1}$, which indicates that there was a greater quantity of electrolytes in the solution in which the seeds of the Pérola cultivar were soaked due to its more permeable membrane. In contrast, in the accelerated aging test (Table 4), the germination percentage was similar between the two cultivars and varied from 95 to 100%, which, considering the addition of desiccants, indicates that the seeds remained viable and were able to germinate even under stress caused by high temperature and humidity.

### *Cooking quality*

The cooking times of the two cultivars were not affected by the treatments (Table 5), and the level of resistance to cooking was scored as "average" according to the Proctor and Watts scale.[26] The cooking time varied from 31 to 35 minutes for the Pérola cultivar and from 29 to 34 minutes for the IPR Juriti cultivar. Regarding their hydration capacities, the beans from both of the cultivars had hydration ratios close to 2, which demonstrates that the beans absorbed approximately twice their weight in water (Tables 6 and 7). Hydration was not affected by the treatments. None of the beans from either cultivar contained a hard seed coat. A difference in the maximum hydration time (MHT) of the beans in response to the applied desiccants was only observed for the IPR Juriti cultivar (Table 7), and the ammonium glufosinate treatment (MHT = 13 h 35 min) was the only treatment that differed from the control (MHT = 11 h 11 min). This treatment also caused a greater hydration time than those for the glyphosate doses, except for the highest dose (1,080 g a.e.ha$^{-1}$). The mean MHT for the Pérola cultivar was 12 h 40 min (Table 7), and the MHT of this cultivar was not affected by the applications of desiccants.The treatments with the herbicide glyphosate did not negatively affect the cooking characteristics for consumption, but it is still necessary to verify if this product leaves any residue on the beans.

## Discussion

Applications of glyphosate and ammonium glufosinate did not compromise the yield or final bean mass of the two bean cultivars, most likely because these characteristics were already defined in most of the plants by the time of application, and only bean filling, which may have been little affected by the desiccants, occurred post-application. However, the vigor tests demonstrated that increased doses of the herbicide glyphosate can delay germination (FCV and IGS) of the bean seeds without compromising the final germination percentages. A drastic reduction in germination and vigor of Carioca bean seeds was found by Penckowski et al. (2005) when they used a dose of 720 g e.a.ha$^{-1}$ of glyphosate as a pre-harvest desiccant and by Kamikoga et al. (2009) when they used doses of 720 and 1,440 a.i. ha $^{-1}$ glyphosate for the bean cultivar Soberano. However, Toledo et al. (2009) found that the initial vigor of soybeans was greater than 85% at a dose of 720 g a.e.ha$^{-1}$ of glyphosate. Ratnayake and Shaw (1992) found no effects on soybean yield, seed germination or seedling development when glyphosate at 560 g a.e. ha$^{-1}$ and glufosinate at 840 g a.i. ha$^{-1}$ were applied at R8 stage, but when applied at R5 to R7 stages, these treatments negatively affect these characteristics. According to these authors, glyphosate reduced soybean germination and seedling vigor when applied at or close to seed physiological maturity. Because glyphosate moves through the plant via the symplastic pathway, product applications in source regions (mature leaves) allow for the translocation of the herbicide to sink regions (of growth) along with photoassimilates in the rest of the plant (Duke et al., 2012). Given this possibility, glyphosate could be translocated to seeds that are forming in mother plants, and as it accumulates in the seeds, the glyphosate could inhibit gibberellic acid (GA) and/or indolylacetic acid (IAA) hormones without killing the embryo but still affecting the speed of the germination process

**Table 1.** Productivity and 100-bean weight of common bean cultivars (Pérola and IPR Juriti) subject to desiccant applications.

| Treatments | Productivity (kg ha $^{-1}$) | | Weight of 100 beans (g) | |
|---|---|---|---|---|
| | Pérola | IPR Juriti | Pérola | IPR Juriti |
| Control | 2427 | 1845 | 29.35 | 28.27 |
| Ammonium glufosinate (360 g a.i. ha$^{-1}$) | 2313 | 1678 | 25.42 | 26.16 |
| Glyphosate (180 g a.e.ha$^{-1}$) | 1851 | 1896 | 28.98 | 27.10 |
| Glyphosate (360 g a.e.ha$^{-1}$) | 2406 | 2165 | 29.46 | 28.22 |
| Glyphosate (720 g a.e.ha$^{-1}$) | 2157 | 2042 | 27.95 | 27.15 |
| Glyphosate (1,080 g a.e.ha$^{-1}$) | 2159 | 1816 | 26.94 | 27.63 |
| F treat. | 0.89 ns | 0.66 ns | 2.69 ns | 1.78 ns |
| MSD | 974.89 | 929.66 | 4.17 | 2.67 |
| CV (%) | 25.01 | 24.92 | 8.48 | 4.86 |

ns - not significant according to the F test.

**Table 2.** Final germination, first count values (FCV) and indices of germination speed (IGS) of bean seeds of the Pérola and IPR Juriti cultivars subjected to desiccant applications.

| Treatment | Final germination (%) | | FCV (%) | | IGS | |
|---|---|---|---|---|---|---|
| | Pérola | IPR Juriti | Pérola | IPR Juriti | Pérola | IPR Juriti |
| Control | 100 | 100 | 77.5 a | 77.0 a | 12.6 a | 14.8 a |
| Ammonium glufosinate (360 g a.i. ha$^{-1}$) | 99 | 100 | 64.0 ab | 73.5 ab | 12.0 a | 12.5 a |
| Glyphosate (180 g a.e.ha$^{-1}$) | 100 | 100 | 58.0 ab | 78.5 a | 12.1 a | 14.9 a |
| Glyphosate (360 g a.e.ha$^{-1}$) | 100 | 98 | 78.0 a | 60.5 b | 7.8 b | 9.5 b |
| Glyphosate (720 g a.e.ha$^{-1}$) | 99 | 97 | 32.5 bc | 43.0 bc | 4.8 bc | 4.4 c |
| Glyphosate (1,080 g a.e.ha$^{-1}$) | 98 | 100 | 11.0 c | 20.5 c | 1.5 c | 2.5 c |
| F treat. | 1.00 ns | 2.29 ns | 12.27** | 70.41** | 7.76** | 9.65** |
| MSD | 8.42 | 8.05 | 34.21 | 42.39 | 7.37 | 7.68 |
| CV (%) | 3.83 | 3.65 | 28.45 | 31.18 | 38.55 | 34.87 |

Means followed by different letters differ by Tukey's test at 5% probability. ** - significant at 1%; ns - not significant by the F test.

**Table 3**. Shoot and root dry mass of common bean cultivars (Pérola and IPR Juriti) in response to desiccant applications.

| Treatment | Dry mass (g plant$^{-1}$) | | | |
|---|---|---|---|---|
| | Shoot | | Root | |
| | Pérola | IPR Juriti | Pérola | IPR Juriti |
| Control | 0.163 | 0.159 | 0.043 a | 0.050 a |
| Ammonium glufosinate (360 g a.i. ha$^{-1}$) | 0.148 | 0.140 | 0.039 ab | 0.024 bc |
| Glyphosate (180 g a.e.ha$^{-1}$) | 0.142 | 0.153 | 0.032 ab | 0.030 bc |
| Glyphosate (360 g a.e.ha$^{-1}$) | 0.165 | 0.160 | 0.029 bc | 0.029 bc |
| Glyphosate (720 g a.e.ha$^{-1}$) | 0.139 | 0.142 | 0.019 cd | 0.014 d |
| Glyphosate (1,080 g a.e.ha$^{-1}$) | 0.126 | 0.129 | 0.012 d | 0.012 d |
| F treat. | 1.54 ns | 1.19 ns | 18.12** | 18.86** |
| MSD | 0.054 | 0.061 | 0.012 | 0.015 |
| CV (%) | 16.31 | 18.87 | 18.48 | 23.57 |

Means followed by different letters differ based on Tukey's test at 5% probability. ** - significant at 1%; ns - not significant by the F test.

**Table 4**. Electric conductivity and percent germination of seeds of the Pérola and IPR Juriti cultivars in response to desiccant applications, as measured after being subjected to the accelerated aging test.

| Treatment | Accel. Aging (G%) | | Electric Cond. (µS cm$^{-1}$ g$^{-1}$) | |
|---|---|---|---|---|
| | Pérola | IPR Juriti | Pérola | IPR Juriti |
| Control | 99 | 98 | 62 | 46 |
| Ammonium glufosinate (360 g a.i. ha$^{-1}$) | 98 | 99 | 66 | 42 |
| Glyphosate (180 g a.e.ha$^{-1}$) | 96 | 95 | 55 | 44 |
| Glyphosate (360 g a.e.ha$^{-1}$) | 94 | 95 | 70 | 49 |
| Glyphosate (720 g a.e.ha$^{-1}$) | 96 | 95 | 54 | 44 |
| Glyphosate (1,080 g a.e.ha$^{-1}$) | 99 | 96 | 59 | 41 |
| F treat. | 4.27 ns | 1.95 ns | 1.91 ns | 2.14 ns |
| MSD | 11.52 | 18.3 | 0.5 | 0.26 |
| CV (%) | 5.35 | 8.52 | 14.65 | 10.14 |

ns - not significant by the F test.

**Table 5**. Cooking time of beans of the Pérola and IPR Juriti cultivars subjected to desiccant applications.

| Treatment | Cooking time (minutes) | |
|---|---|---|
| | Pérola | IPR Juriti |
| Control | 33 | 32 |
| Ammonium glufosinate (360 g a.i. $ha^{-1}$) | 34 | 29 |
| Glyphosate (180 g a.e.$ha^{-1}$) | 35 | 34 |
| Glyphosate (360 g a.e.$ha^{-1}$) | 34 | 33 |
| Glyphosate (720 g a.e.$ha^{-1}$) | 32 | 32 |
| Glyphosate (1,080 g a.e.$ha^{-1}$) | 31 | 32 |
| F treat. | 0.56 ns | 0.37 ns |
| MSD | 11.66 | 12.09 |
| CV (%) | 8.8 | 16.44 |

ns - not significant by the F test.

**Table 6**. Maximum hydration times (MHT) and hydration ratios (HR) of beans of the Pérola cultivar subjected to desiccant applications

| Treatment | Pérola | | | |
|---|---|---|---|---|
| | Equation | $R^2$ | MHT (h) | HR |
| Control | $y = -0.00008x^2 + 0.1201x + 3.3061$ | 0.99 | 12:15 | 2.00 |
| Ammonium glufosinate (360 g a.i. $ha^{-1}$) | $y = -0.00006x^2 + 0.1138x + 0.4964$ | 0.99 | 12:23 | 2.01 |
| Glyphosate (180 g a.e.$ha^{-1}$) | $y = -0.0001x^2 + 0.1389x + 5.4479$ | 0.97 | 12:40 | 1.98 |
| Glyphosate (360 g a.e.$ha^{-1}$) | $y = -0.0001x^2 + 0.1463x + 3.8189$ | 0.98 | 13:18 | 1.99 |
| Glyphosate (720 g a.e.$ha^{-1}$) | $y = -0.00008x^2 + 0.1272x + 1.9245$ | 0.99 | 11:19 | 2.02 |
| Glyphosate (1,080 g a.e.$ha^{-1}$) | $y = -0.00008x^2 + 0.124x + 2.9282$ | 0.99 | 13:28 | 2.02 |
| F treat. | | | 0.68 ns | 1.91 ns |
| MSD | | | 2.51 | 0.05 |
| CV (%) | | | 9.14 | 1.14 |

x = hydration time (minutes) and y = quantity of water absorbed (mL). $R^2$ = coefficient of determination. ns - not significant by the F test.

**Table 7.** Maximum hydration times (MHT) and hydration ratios (HR) of beans of the IPR Juriti cultivar subjected to desiccant applications.

| Treatment | IPR Juriti | | | |
|---|---|---|---|---|
| | Equation | $R^2$ | MHT (h) | HR |
| Control | $y = -0.00008x^2 + 0.1201x + 3.3061$ | 0.99 | 11:11 b | 1.94 |
| Ammonium glufosinate (360 g a.i. $ha^{-1}$) | $y = -0.00006x^2 + 0.1138x + 0.4964$ | 0.999 | 13:35 a | 1.89 |
| Glyphosate (180 g a.e.$ha^{-1}$) | $y = -0.0001x^2 + 0.1389x + 5.4479$ | 0.975 | 11:28 b | 1.94 |
| Glyphosate (360 g a.e.$ha^{-1}$) | $y = -0.0001x^2 + 0.1463x + 3.8189$ | 0.985 | 10:44 b | 1.90 |
| Glyphosate (720 g a.e.$ha^{-1}$) | $y = -0.00008x^2 + 0.1272x + 1.9245$ | 0.996 | 11:14 b | 1.93 |
| Glyphosate (1,080 g a.e.$ha^{-1}$) | $y = -0.00008x^2 + 0.124x + 2.9282$ | 0.993 | 12:14ab | 1.94 |
| F treat. | | | 6.30 ** | 2.73 ns |
| MSD | | | 2.12 | 0.05 |
| CV (%) | | | 8.43 | 1.35 |

x = hydration time (minutes) and y = quantity of water absorbed (mL). $R^2$ = coefficient of determination. Means followed by different letters differ based on Tukey's test at 5% probability. ** - significant at 1%; ns - not significant by the F test.

by delaying it. IAA, a hormone that is synthesized in the apical regions of the plant (roots and stems), is related to growth regulation and derived from the amino acid tryptophan through a number of steps. Independently of tryptophan, indole-3-glycerol phosphate, which depends on chorismate for its formation, is another precursor of IAA. Glyphosate inhibits the synthesis of both chorismate and tryptophan (Duke et al., 2012). This inhibition of IAA by glyphosate could have negatively affected root growth in seedlings when doses were greater than 360 g.a.e.$ha^{-1}$ for the cultivar Pérola. A reduction in the length of the primary root in soy seedlings was also observed by Toledo et al. (2009), who used glyphosate doses of 720 g a.e.$ha^{-1}$ as a pre-harvest desiccant. Inhibitory effects of glyphosate applied pre-harvest on conventional soybean seedling root development were also found by Daltro et al. (2010) and alfalfa (Moyer et al., 1996). Even when the seeds were subject to thermal stress and humidity to accelerate aging, the desiccants did not affect germination, which indicates that the desiccants do not affect the integrity of the embryo and that they most likely do not compromise the integrity of the cellular membranes. This finding is supported by the electric conductivity results and by the finding that desiccants did reduce the levels of lignin in the integument (Panobianco and Vieira, 1996). Cooking time can be affected by crop conditions, processing, or bean storage (Ribeiro et al., 2007). Regarding crop conditions, the application of desiccants during pre-harvest did not affect the bean cooking time, and the results were similar to those obtained by Mingotte et al. (2013) for beans collected from the same region and also for the IPR Juriti cultivar but without the application of desiccants (33 to 40 minutes). Cooking time is related to the hydration capacity of beans and is shorter with greater hydration capacity. According to Carbonell et al. (2003) and Lemos et al. (2004), maximum bean hydration times vary according to genotype and the environmental conditions to which beans are subject throughout their development. In the present study, the beans exhibited excellent hydration capacities, practically doubling in weight, without any observed effect of the desiccants, regardless of cultivar. These results are similar to those obtained by Lemos et al. (2004), who did not apply desiccants.

## Materials and Methods

### *Site and sowing*

The experiments were conducted in the state of São Paulo, Brazil (latitude 21°15’22”, longitude 48°18’58”, and altitude of 595 m) from July to September 2012. The soil was a clayey Red Eutrophic Latosol, and the soil was prepared by first plowing and then disking twice. The seeds were sown on 18 June 2012. The space between rows was 0.45 m, with a density of 14 seeds per meter.

### *Experimental design*

The experimental design was a completely randomized design with five replicates. The plots were composed of five sowing lines five meters in length. The two external lines and the half of a meter at the beginning and end of each plot were considered borders and were discarded; thus, the total usable area per plot was 3.6 $m^2$. The experiment was conducted without any water restrictions using a spray irrigation system.

### *Treatments and plant material*

The treatments included four doses of glyphosate (Roundup Original$^R$: 180, 360, 720, and 1,080 g a.e. $ha^{-1}$), the standard 360 g a.i. $ha^{-1}$ ammonium glufosinate (Finale$^R$), and a control with no product application, comprising a total of six treatments that were conducted for two bean cultivars of the Carioca commercial group Pérola, which has a type II/III intermediate growth and semi-erect stature, and IPR 139 (Juriti Claro), which has an undetermined type II growth and erect stature (EMBRAPA, 2013). The weeds that emerged during the experimental period were controlled post-emergence with the herbicides fluazifop-p-butyl + fomesafen (120 + 150 g a.i. $ha^{-1}$).

### *Treatments application and analysis*

The desiccants were applied during phenological stage R9 (maturation) of the crop, characterized by discoloration and pod drying in 50% of the plants (Fernandez et al., 1992), which occurred 74 days after sowing (DAS). Desiccants were applied with a backpack sprayer (equipped with a bar with four XR 110.02 nozzles at a spacing of 0.5 m) at a constant pressure (maintained by compressed $CO_2$) of 28 lbf $in^2$ and a solution volume of 200 L $ha^{-1}$. The edaphic and climatic conditions at the time of application were as follows: moist soil, 18.8 ºC air temperature; 68% relative air humidity, 4 km $h^{-1}$ wind speed, and 0% cloud cover. The harvest was performed 13 days after treatment applications (87 DAS), and the productivity (obtained by the mass of beans from the usable area after standardizing for 13% humidity) and dry weight of 100 beans were determined. The beans were then stored in a cold and dry chamber (+/-10 ºC and 20% relative humidity) until the laboratory tests of the physiological and cooking qualities were performed. The samples used in the tests were classified in an oblong 12/64” sieve. The following factors were measured to determine the physiological quality related to seed production: germination, first count value (FCV), and accelerated aging (all following methods described in Brasil, Ministério da Agricultura (2009), index of germination speed (IGS), electric conductivity, and dry mass of the shoots and roots of 20 typical seedlings, after drying in a forced-air oven at 70 ± 2ºC for 96 hours, expressed in mg $plant^{-1}$. The following factors were measured to determine the cooking quality of the beans: cooking time in a Mattson cooker, score on the Proctor and Watts scale and hydration capacity, as described by Mingotte et al. (2013) and Lemos et al. (2004).

### *Statistical analysis*

The results were submitted to analysis of variance by the F test, and the means were compared using Tukey tests at the 5% probability level.

## Conclusions

The use of the herbicide glyphosate up to a rate of 1,080 g a.e. $ha^{-1}$ as a desiccant against weeds in the pre-harvest period is possible for the bean market. However, if the harvested product is destined for the planting of a new crop, caution should be observed with this herbicide because high doses reduce the first count value, germination speed, and root dry mass of bean seedlings.

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