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Quality of Black Bean Seeds Submitted to Pre-Harvest Desiccation by Different Active Principles and Application Times

Qualidade de Sementes de Feijão-Preto Submetidas à Dessecação Pré-Colheita por Diferentes Princípios Ativos e Épocas de aplicação

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Abstract

The objective of this study was to evaluate the ideal dissecation moment and how different active principles influence the yield and the physical and physiological quality of black beans seeds, cultivar BRS Esteio. The experiment was carried out in the 2018/2019 harvest in the municipality of Pato Branco, Paraná. Sowing was carried out on 07/11/2018 and the experimental design adopted was randomized blocks (DBA), with four replications. Treatments were arranged in a 4 x 4 factorial scheme (four herbicides x four application times). Desiccants were applied when the culture presented 60%, 70%, 80% and 90% of the pods at the field maturation stage. And the active principles and doses used were: diquate (400 g a.i. ha^{-1}), glufosinate – ammonium salt (400 g a.i. ha^{-1} + mineral oil), saflufenacil (49 g a.i. ha^{-1}) and potassium glyphosate (1,240 g a.i. ha^{-1}). Post-harvest evaluations were as follows: weight of one thousand seeds (g), yield (kg ha^{-1}), germination test (%), accelerated aging test (%) and length of aerial part and seedlings root (cm). Regardless of the active principle used, aiming at the seeds production, the cultivar desiccation of BRS Esteio black beans, must be performed when 60% of the pods are at the field maturation stage. In addition, dried seeds with glufosinate - ammonium salt resulted in heavier seeds and more vigorous seedlings, contrary to the observed for the potassic glyphosate that reduced the seedlings vigor.

Keywords: *Phaseolus vulgaris* L. Herbicides. Maturation. Physiological Quality. Seeds Technology.

Resumo

O objetivo deste estudo foi avaliar o momento ideal de dessecação e de que forma diferentes princípios ativos influenciam a produtividade e a qualidade física e fisiológica de sementes de feijão-preto, cultivar BRS Esteio. O experimento foi conduzido na safra 2018/2019, no município de Pato Branco, Paraná. A semeadura foi realizada no dia 07/11/2018 e o delineamento experimental adotado foi de blocos ao acaso (DBA), com quatro repetições. Os tratamentos foram arranjados em esquema fatorial 4 x 4 (quatro herbicidas x quatro épocas de aplicação). A aplicação dos dessecantes foi realizada quando a cultura apresentou 60%, 70%, 80% e 90% das vagens no estágio de maturação de campo. E os princípios ativos e doses utilizadas foram: diquate (400 g de i.a. ha^{-1}), glufosinato – sal de amônio (400 g de i.a. ha^{-1} + óleo mineral), saflufenacil (49 g de i.a. ha^{-1}) e glifosato potássico (1.240 g de i.a. ha^{-1}). As avaliações pós-colheita foram as seguintes: peso de mil sementes (g), produtividade (Kg ha^{-1}), teste de germinação (%), teste de envelhecimento acelerado (%) e comprimento de parte aérea e raiz de plântulas (cm). Independente do princípio ativo utilizado, visando a produção de sementes, a dessecação da cultivar de feijão-preto BRS Esteio, deve ser realizada quando 60% das vagens se encontram no estágio de maturação de campo. Além disso, as sementes dessecadas com glufosinato – sal de amônio, resultaram em sementes mais pesadas e em plântulas mais vigorosas, contrariamente ao observado para o glifosato potássico que reduziu o vigor de plântulas.

Palavras-chave: *Phaseolus vulgaris L. Herbicides. Maturation. Physiological Quality. Seed Technology.*

1 Introduction

Beans cultivation is widespread in almost all of the Brazilian territory. In addition to being the main protein source in the feeding of the neediest population, beans also have a good carbohydrate content and are rich in iron (VIEIRA *et al.,* 2006). The national production recorded in the 2017/18 harvest was 3,116.1 thousand tons, and the South region has a major highlight in the national scenario, accounting for approximately 26.4% of total beans production. The state of Paraná is currently classified as the largest Brazilian leguminous producer, with a production of 587.4 thousand tons, of which 54% is black beans (National Supply Company (CONAB, 2019).

According to Vieira *et al.* (2006), the majority of the beans varieties produced in Brazil are undetermined growth habit of types II and III, that is, flowering happens sequentially and the same occurs with the fruits, which makes maturation very uneven. Therefore, one of the difficulties found, according to Penckowski *et al.* (2005), is that due to this, harvest becomes a very critical step, because at this moment the seeds present high water content and large amounts of green leaves and branches, making the harvesting operation impractical.

In order to alleviate all these problems found at the harvest time, the option is to use, when most plants reach physiological maturation, synthetic products, the so-called desiccants. These help to anticipate the harvest, due to the plants rapid drying, accelerate the fall of the leaves and the loss of moisture in the seeds and standardize the maturation (SILVA *et al.,* 1999). Thus, it is possible to obtain seeds with high physiological quality and yield (INOUE *et al.,* 2003). However, to use these desiccants, some aspects should be taken into account, among them, the use of the most indicated herbicide, its efficiency and influence on the yield and seeds physiological quality and the ideal time of application (SANTOS *et al.,* 2004; TOLEDO *et al*., 2014).

In view of the above, there is a need to study the effect that different active principles (desiccant herbicides) can have on the quality of black bean seeds, as well as on their yield, at different times of application.

2 Material and Methods

The experiment was implemented on November 7th, 2018, by mechanized sowing in a no-tillage area, in the municipality of Pato Branco – Paraná. A randomized block design (DBA) was used in a bifactorial scheme (four desiccating herbicides x four desiccation times), with four replications. Each experimental unit was composed of seven lines with 4 m length, spaced 0.5 m.

The seeds of the black bean cultivar BRS Esteio were treated with thiamethoxam (300 mL 100 kg of seeds $^{-1}$) and distributed in the field with a population of approximately 280 thousand plants ha $^{-1}$. In the base fertilization, 300 kg ha $^{-1}$ of the formulated 8-20-15 were used, applied in the sowing line.

The herbicides used were diquate (400 g a.i. ha^{-1}), glufosinate – ammonium salt (400 g a.i. ha^{-1} + mineral oil), saflufenacil (49 g a.i. ha^{-1}) and potassium glyphosate (1,240 g a.i. ha^{-1}).

The dissecants application were performed in four seasons, determined through percentage of pods at the field maturation stage 60% (January 26th, 2019), 70% (February 1st), 80% (February 7th) and 90% (February 11th). In order to characterize the plants that were at this stage, visual aspects of five plants per plot were analyzed, in which the pods yellowish color was observed, the mature grains and the bluish black color. All applications were performed with a CO^2 backpack gas pressurized sprayer.

The manual harvests were carried out in four stages, the first being on February 2nd, 2019, the second on day 08th, the third on day 14th and the fourth on the 23rd of the same month.

After harvest, the plants were threshed and the seeds were forwarded to the seed Analysis Laboratory (LDAS) of Universidade Tecnológica Federal do Paraná (UTFPR), *Campus* Pato Branco, for the following determinations:

Yield (PROD): The plants of the five central lines of each experimental unit with a length of 3 m each line were used, totaling a useful area of 6 m². The seeds were threshed, weighed and the result obtained was corrected to 13% moisture, extrapolated to one hectare (10,000 m²) and expressed in kg ha $^{-1}$.

Weight of one thousand seeds (PMS): Determined with eight repetitions of 100 seeds for each experimental unit, according to the Rules for Seed Analysis (BRAZIL, 2009).

Germination test (GERM): Carried out with four replicates of 50 seeds each, at a temperature of 25 degrees C and the evaluations were carried out according to the rules for seed analysis (BRAZIL, 2009).

Accelerated aging test (EA): 200 seeds were distributed on a gerbox-type suspended screen, containing 40 mL of distilled water, which were kept in an EA chamber at 42 ^{0}C for 72 hours. After that, the seeds were placed to germinate in four replicates of 50 seeds and the evaluation was carried out at five days after the installation. The results were expressed as percentage of normal seedlings (BRAZIL, 2009). In parallel to this test, the seeds moisture content was determined after EA, using the greenhouse method at 105 ºC for 24 hours. The moisture did not exceed the limit from 3 to 4% in any of the analyzed samples, indicating that the procedures used in the test were adequate (KRZYZANOWSKI *et al.,* 1999).

Length of aerial part (COMPPA) and seedlings root (COMPRA): 12-seed four repetitions were used, which were distributed in one line in the upper third of the germitest paper and maintained in the same conditions as the germination test (BRAZIL, 2009). After nine days, the aerial part of the roots of each seedling was separated and measured with a millimeter ruler. The result was expressed in centimeters (KRZYZANOWSKI *et al.,* 1999).

For statistical analysis, the data regarding the moisture and germination variables did not obtain normal distribution and homogeneity of variance, by the Lilliefors and Bartllet test, respectively, were transformed into a sine arch, as follows: $Y_{ij}^{*} = (arcsine(\sqrt{(Y_{ij}/100)})$,, where Y_{ij} is the value observed in the experimental unit that received treatment i in repetition j. (Está tudo ok, obrigado).

After that, variance analysis was performed (ANOVA) followed by individual or joint polynomial regression (in case of interaction between the factors) and Tukey test for comparison of herbicide averages. In all the analyzes, 5% probability of error was adopted. The analyzes were performed in the genes software (CRUZ, 2013) and the figures were elaborated in the Sigma Plot® software (SYSTAT SOFTWARE, SAN JOSE, CA).

3 Results and Discussion

The interaction between the two factors was significant ($p<0.05$) for COMPPA and COMPRA (Table 1).

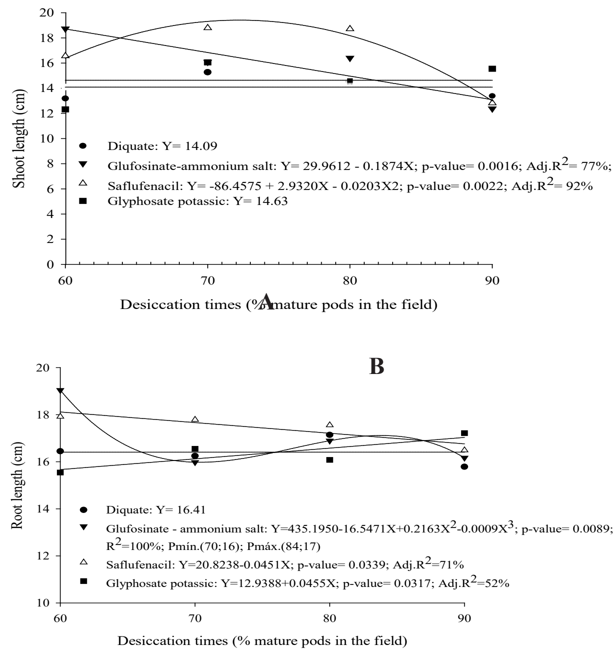
Table 1 - Degrees of freedom (GL) and F statistics of variance analysis for variables, seed yield (PROD – kg ha^{-1}), weight of one thousand seeds (PMS – g), germination (GERM – %), accelerated aging (EA – %), length of aerial part (COMPPA – cm) and root length (COMPRA – cm), of a bifactorial experiment with four desiccants (diquate, glufosinate – ammonium salt, saflufenacil and glyphosate potassium) and four times of desiccation (60, 70, 80 and 90% of the pods in field maturation), conducted in a randomized block design. Pato Branco – PR, 2018/2019

Causes of variation	GL	Statistics F		
		PROD (Kg ha^{-1})	PMS (g)	GERM (%)[1]
Blocks	3	0.7722^{ns}	0.8897^{ns}	0.2490
Herbicides	3	3.7508*	3.2165*	1.6676 ^{ns}
Times of application	3	6.8056*	1.2307^{ns}	30.0488*
Herbicides x times	9	0.8259^{ns}	1.1110^{ns}	0.9058^{ns}
Residue	45	-	-	-
Overall average	-	3164.00	210.72	86.56
CV (%)	-	10.79	2.85	5.91
Causes of variation	**GL**	**Statistics F**		
		EA (%)	**COMPPA (cm)**	**COMPRA (cm)**
Blocks	3	1.5752	1.4154^{ns}	3.6705*
Herbicides	3	2.1493^{ns}	4.4754*	2.4002^{ns}
Times of application	3	17.4564*	3.6386*	5.1620*
Herbicides x times	9	1.9024^{ns}	2.4256*	4.2952*
Residue	45	-	-	-
Overall average	-	81.85	15.34	16.80
CV (%)	-	7.68	16.33	5.46

* Significant at 5% probability of error level. ^{ns} not significant at 5% error probability level. [1]Variable transformed with arcsin square root transform.
Source: Research data.

For the variable COMPPA (Figure 1A), with the use of diquate and potassic glyphosate desiccants, there was no adjusted equation and the means were very close, 14.09 cm and 14.63 cm, respectively. The authors Daltro *et al.* (2010) and Inoue *et al.* (2012) working with soybean desiccation with the herbicide diquate, they observed that, regardless of desiccation time, COMPPA was not significantly affected. On the other hand for the herbicide glyphosate, Daltro *et al.* (2010) reported that for both soybean cultivars used (Conquista and Tucunaré), as desiccation was performed outside the physiological maturation period, the length of seedlings decreased.

Figure 1 - Length of aerial part, in cm (A) and root length, in cm (B) of the cultivar BRS Esteio, due to the interaction among the desiccants (diquate, glufosinate – ammonium salt, saflufenacil and glyphosate potassic) and desiccation times (60, 70, 80 and 90% of the pods in field maturation), in an experiment conducted in a randomized block design. Pato Branco – PR, 2018/2019



Source: Research data.

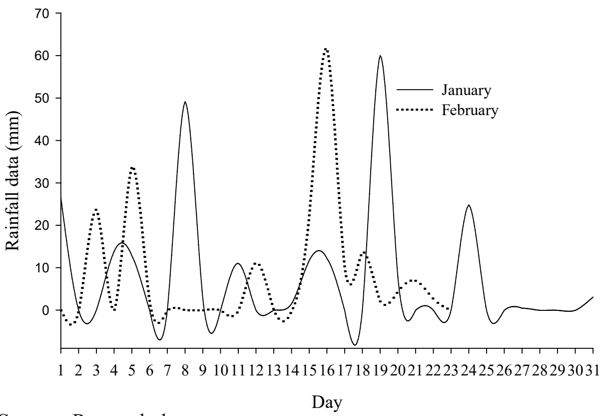
When saflufenacil was used, a quadratic response was obtained according to the times of desiccation (Figure 1A), and the highest COMPPA (19.41 cm) occurred when desiccation was performed with 72% of the pods at the field maturation stage. For the herbicide glufosinate - ammonium salt, as desiccation had been delayed, COMPPA had been decreasing. COMPPA was 18.74 cm and 12.38 cm for the first and last desiccation times, respectively.

For COMPRA (Figure 1B) each desiccant responded differently from the desiccation season. The herbicide diquate influenced COMPRA in the same way as it influenced COMPPA, that is, there was no equation adjustment and the overall average was 16.41 cm. Inoue *et al.* (2012) by testing desiccation stages in soybean with the herbicide diquate also observed that the length of radicle was not influenced by desiccation times.

For the herbicide glufosinate - ammonium salt the response was cubic in relation to desiccation times (Figure 1B), and the maximum point (Pmax) occurred in desiccation with 84% of pods at field maturation stage, resulting in a root length of 17 cm, the minimum point (Pmin) occurred when the plants were dried with 70% of ripe pods, corresponding to 16 cm of COMPRA.

The amount of rain that occurred after each desiccation until the respective harvest influenced the seeds physiological quality (Figure 2). It can be seen that the seeds that received more water, after being dried, were the ones that suffered the greatest vigor deterioration and reduction. The rainfall volume occurred in the dry experimental units at the first applicatjon time (60%) was 3.6 mm, whereas in the second season (70%) it was 59.4 mm. This explains the occurrence of Pmin in desiccation with 70% of ripe pods. The third (80%) and fourth (90%) desiccation times received accumulated rainfalls of 11.30 mm and 136.10 mm, respectively, once again confirming that the seeds that were exposed to higher moisture in the pre-harvest were the ones that had their vigor impaired.

Figure 2 - Rainfall data (mm) during the first application time (01/23/2019) until the last harvest (02/23/2019) with cultivar BRS Esteio, in a bifactorial experiment (dissecants diquate, glufosinate – ammonium salt, saflufenacil and glyphosate potassic x application times 60, 70, 80 and 90% of the pods in field maturation), conducted in a randomized block design. Pato Branco – PR, 2018/2019



Source: Research data.

The seed exposure to alternating cycles of high and low humidity before harvest, due to the occurrence of frequent rains, causes the seeds to suffer deterioration by moisture (FRANÇA-NETO *et al.,* 2016). By using desiccants, the seeds moisture can be reduced quickly and thus advance the harvest. However, if desiccation is carried out and soon after, there are several days of rain, the seeds quality becomes even more impaired, since they would be relatively ready to be harvested, but due to adverse climatic conditions they will suffer deterioration in the field, what according to Henning (2005) occurs mainly by the fungi action.

For the desiccant saplufenacyl (Figure 1B) the later the desiccation time was, the shorter the root length was, reducing from 17.92 cm in the first desiccation season to 16.49 cm in the last season.

When the glyfosate potassium desiccant was used, it was observed (Figure 1B) that as desiccation was delayed, the COMPRA variable was increased in size from 15.55 cm (desiccation 60%) to 17.22 cm (desiccation 90%). Similar report was made by Daltro *et al.* (2010) in desiccation of soybean (Conquista and Tucunaré cultivars), where when the herbicide glyphosate potassic was used in the first desiccation season (R6.5), it originated seedlings of shorter length in relation to the R7 season. According to Roman *et al.* (2005), this occurs because glyphosate has water as a transport agent, i.e. the greater the amount of water in the seeds, the greater the desiccant opportunity to reach the seed deeper tissues and cause damage.

There was a significant effect of desiccants ($p<0.05$) for the variables PROD, PMS and COMPPA (Table 1).

Although it did not differ statistically from other herbicides, glufosinate - ammonium salt resulted in higher averages than the others for all the variables (Table 2).

Table 2 - Comparison of means of dissecant herbicidaes for the variables, seed yield (PROD – kg ha $^{-1}$), weight of one thousand seeds (PMS – g), and length of aerial part (COMPPA – cm) of a bifactorial experiment with four desiccants (diquate, glufosinate – ammonium salt, saflufenacil and glyphosate potassium) and four times of desiccation (60, 70, 80 and 90% of the pods in field maturation), conducted in a randomized block design. Pato Branco – PR, 2018/2019

Desiccant herbicides	PROD	PMS	COMPPA
Diquate	3263.30 ab*	207.74 b	15.20 ab
Glufosinate - ammonium salt	3322.37 a	214.21 a	16.55 a
Saflufenacil	2952.37 b	210.97ab	16.06 a
Potassium glyphosate	3118.29 ab	209.94 ab	13.54 b

*Means not followed by the same letter differ from each other at the level of 5% probability of error by the Tukey test.
Source: Research data.

Considering yield, the only herbicides used that differed among each other were glufosinate – ammonium salt and saflufenacil, the first with the best performance. For the PMS variable, potassic glyphosate and the collufenacyl did not show any statistical difference neither for the best (glufosinate - ammonium salt) nor for the worst desiccant (diquate). This result is contrary to what Guimaraes *et al.* (2012) observed, who concluded in a study with paraquat desesescants, ammonium glufosinate and glyphosate, in doses of 400, 400 and 960 g a.ia ha $^{-1}$, respectively, applied in three stages (R6, R7.2 and R8.1) of soybean crop, that none of them is able to reduce yield.

The results of PMS and PROD found in the present study and regarding potassic glyphosate, reinforce the positioning of Cunha *et al.* (2005), Monquero *et al.* (2012) and Pereira *et al.* (2011), who said that the herbicide acts more slowly in the plant, allowing the grains filling for longer after desiccation and in counterpoint to that are saflufenacil and diquate, which desiccate the plant rapidly, interrupting the photoassimilates transport, thereby reducing the grain weight and size .

For the variable COMPPA, glufosinate - ammonium salt resulted in higher averages, although it has not differed statistically from collufenacyl and diquate (Table 2). According to Dan *et al.* (1987), more vigorous seeds are responsible for generating more developed seedlings, since they have higher processing capacity and longer storage tissue reserves and greater use of these by the embryonic axis. Thus, the results obtained for the variable COMPPA indicate that glufosinate - ammonium salt is the herbicide that results in more vigorous seeds compared to the others.

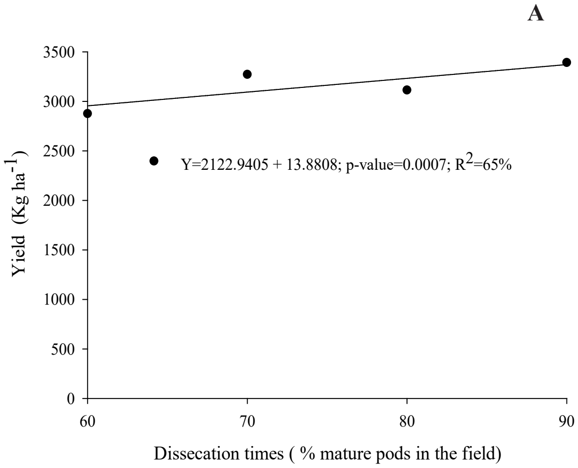
The herbicide glyphosate potassic was the one with lower averages, although it did not have a statistical difference in diquate. Bervald *et al.* (2010) and Daltro *et al.* (2010) corroborate this result by reporting that soybean seeds desiccation, for most of the cultivars used, desiccation with glyphosate promotes shorter seedling length compared to other desiccants.

These results can be explained by the work of Monquero *et al.* (2012), Pereira *et al.* (2011) and Roman *et al.* (2005), in which there are reports that the herbicides glufosinate – ammonium salt, diquate and saflufenacil dry the plants quickly, limiting the movement and possibility of damaging the seeds. Moreover, according to Roman *et al.* (2005), glufosinate – ammonium salt has its translocation limited due to the rapid inhibitory photosynthesis action, and thus the herbicide does not have enough time to reach the seeds deeper tissues and cause damage to its quality.

On the other hand, the herbicide glyphosate potassic has an opposite effect and negatively affects the seeds quality, especially regarding vigor, because its penetration occurs slowly, due to the very low value of its water octanol partition coefficient (-4) compared to other herbicides, which gives it low lipophilicity and high water solubility (MAC ISAAC *et al.,* 1991), allowing such a herbicide to present capacity and time to reach the deepest seed tissues.

There was a significant isolated effect ($p<0.05$) of desiccation times for all the variables, except for PMS (Table 1). For the variable EA (Figure 3C), as desiccants were delayed, there was a significant linear decrease. GERM (Figure 3B) also decreased in later applications, however, for this, a quadratic adjustment was obtained with a minimum technical efficiency point outside the studied range, therefore without an adequate practical explanation.

Figure 3 - Yield in Kg ha^{-1} (A), germination, in % (B) and accelerated aging, in % (C) of the beans cultivar BRS Esteio, in function of dissecation times, in a bifactorial experiment (dissecants diquate, glufosinate – ammonium salt, saflufenacil and glyphosate potassic x application times 60, 70, 80 and 90% of the pods in field maturation), conducted in a randomized block design. Pato Branco – PR, 2018/2019



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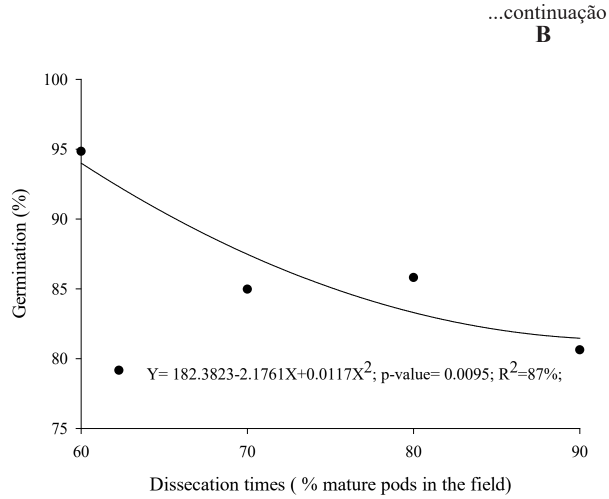

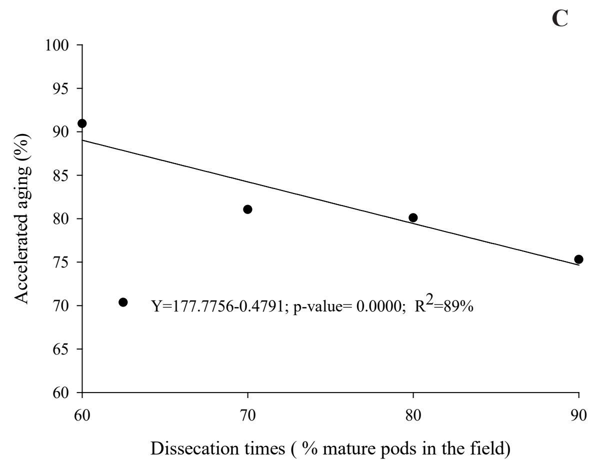

Source: Research data.

The fact that the values of these variables have decreased after one period occurs because the plants reach a point of physiological maturation, in which the maximum physiological quality occurs (PELÚZIO *et al*., 2008). From this point on, the seeds permanence in the field reduces the germination and vigor, probably due to the effect of adverse environmental conditions. In the present experiment, physiological maturation was achieved close to the first desiccation season, because it was precisely at this time when the highest GERM (94.84%) (Figure 3C) and EA (90.94%) were obtained (Figure 3D). Several authors found similar results to that . Silva *et al.* (2016) observed that for the beans cultivars Iraí and BRS Expedito, there was a decrease in GERM as the harvest was delayed. Lamego *et al.* (2013) and Marcandelli *et al*. (2011), working with soybean seeds desiccation, observed that as applications were carried out outside the physiological maturation stage, the seedlings germination and vigor decreased.

Yield (Figure 3A) had an opposite effect to the other variables, since as desiccation was delayed, yield increased. This is due to the fact that, when 60% of the pods were ripe (first desiccation time), the other 40% were still receiving photoassimilates, that is, filling grain. At the desiccation time, the transfer of substances from the mother plant to the seed was ceased (MARCOS FILHO, 2005), causing a reduction in yield at the first application time, since 40% of the pods still did not have grains in physiological maturity, characterized as the moment when a seed presents its greatest accumulation of dry matter (ROSADO *et al.,* 2019). Therefore, the results obtained in the present study allow the bean producer to be alerted to a number of aspects that must be taken into account before pre-harvest desiccation is performed. Thus, the following points stand out: 1st) when dealing with bean seeds, desiccation of the cultivar BRS Esteio should not be carried out with the herbicide glyphosate potassium, since this treatment negatively affected the seedlings vigor (evaluation of COMPPA); 2nd) in order to obtain seeds with better physiological quality, desiccation is recommended when 60% of the pods are ripe and 3rd) in the case of crops for grain production and for high yields, desiccation of this cultivar can be performed later, with 90% of mature pods, giving priority to the herbicide glufosinate - ammonium salt.

4 Conclusion

The results found in the present study reveal that regardless of the active principle used, aiming at the seeds production, desiccation of the cultivar of BRS Esteio black beans, must be performed when 60% of the pods are at the field maturation stage. Still, plants dissecated with the herbicide glufosinate - ammonium salt result in heavier seeds and more vigorous seedlings and potassium glyphosate desiccant reduces seedlings vigor.

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