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RESEARCH ARTICLE

HERBICIDE APPLICATION TIMING IN PRE HARVEST DESICCATION OF SOYBEAN: IMPACT ON GRAIN YIELD AND PHYSIOLOGICAL QUALITY OF SEEDS

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ABSTRACT

The desiccation in soybean pre-harvest is a practice that allows early harvest, uniformity of ripeness, weed management, minor impurities and the anticipation of crops. The objective of this study was to evaluate the effects of desiccant application time in the pre-harvest of soybean (*Glycine max L.)* on the early harvest, grain yield and physiological quality of soybean seeds. The work consists of two steps: one experiment conducted in the field in the municipality of Três Passos, Rio Grande do Sul, Brazil in the agricultural year 2014/2015 and another experiment in Seed Technology Laboratory of University of Santa Maria, Campus de Frederico Westphalen. The treatments consisted of four growth stages of application of the herbicide paraquat (480 g a.i. ha^{-1}), in soybean reproductive stages: R7.1, R7.2, R7.3, R8.1 and control (without desiccation). Evaluated the thousand seed weight, grain yield, germination, first count, normal and abnormal plants. With application of paraquat desiccant was possible to anticipate the soybean harvest from four to nine days. When seeking productivity and physiological quality of seed desiccation of soybean have to be prioritized in the R7.3 stage.

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INTRODUCTION

harvesting time and the environmental conditions during the period that the seeds remain in the field after their physiological maturity have been identified with the main factors that affect the physiological potential of seeds. In general, the physiological maturity is when the seeds have a maximum dry matter, germination and vigor (Carvalho and Nakagawa, 2012). Seed quality decreased, mainly due to the temperature and humidity in which these are exposed to be harvested (Garcia *et al*., 2004). Therefore, the early harvest has been identified as a practice that reduces the risk of deterioration of the seeds in the field and obtains better quality seeds (Terasawa *et al*., 2009). According to Inoue *et al*. (2012), early soybean harvest aims sowing a second crop, and allow better planning of crop rotation and optimize reception, drying and processing of seeds (Veiga *et al*., 2007). Generally, the delayed harvest associated with increased seed coat cracks percentage and variation of relative humidity, causes various damages to the seeds, such as increasing the deterioration process due to the ease of penetration of pathogens and increased exposure of embryonic tissue to the environment (Marcandalli *et al*., 2011). So any strategy that can contribute to the preservation of seed quality are beneficial and among them is the anticipation of the harvest, and as an alternative the use of desiccants (Daltro *et al*., 2010), allowing rapid loss of water (Lacerda *et al*., 2001). In this sense, Nakashima *et al*., (2000) obtained seeds with high physiological quality and without significant reduction in productivity with applications of paraquat in the R6.5 stage, anticipating the harvest of crops in 11 and 7 days, respectively. Evaluating physiological, biochemical and sanitary characteristics of soybean seeds harvested after desiccation with four desiccant, Lacerda (2003) observed that the germination of seed from desiccated plants to glufosinate ammonium was less when compared to desiccation made with paraquat, diquat and mixtures thereof. In this practice of soybean desiccation, the main herbicide used for earlier harvesting has been paraquat. According to Vargas and Roman (2006), paraquat is a non-selective herbicide used post-emergence, with reduced translocation in the plant (contact)

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and low persistence in soil being used for full control of vegetation. When the use of desiccants in the pre-harvest of soybeans, some key aspects should be considered with respect to its use as an herbicide choice and the ideal time of your application, so there is no loss in productivity and mainly quality physiological seeds. Given the limited information in the literature, it is essential to carry out studies that can assist in making crop management decision (Guimarães *et al*., 2012), by technicians and producers. This is because earlier application may result in significant losses of soybean yield and germination and seed vigor. On the other hand, if the application was very late these not represent earlier harvesting which can thwart the main objective of this practice. Therefore, the objective of this study was to evaluate the effects of time of application of pre-harvest desiccant in soybean crop (*Glycine Max L.*) on the early harvest, grain yield and seed quality.

MATERIAL AND METHODS

The work was performed in two stages, the first field and the second in the laboratory. The field experiment was conducted in the municipality of Três Passos, Rio Grande do Sul, in southern Brazil, the agricultural year of 2014/15, whose coordinates are 27°31'S and 53°49' W, at an altitude of 420 meters. The soil is classified as Rhodic Hapludox soil, or sandy clay loam soil in the Brazilian System of Soil Classification (Embrapa, 2013) with texture clayey. The climate according to Koppen classification, it is subtropical with wet spring, with average annual temperature of 19ºC and annual rainfall of 1.900 mm. The experimental design was a randomized complete block design with four replications. Treatment factor consisted of four periods of application of the herbicide paraquat in different developmental stages of soybean: R7.1 (50% of yellowing of leaves and legumes), R7.2 (50 e 75% of yellowing of leaves and legumes), R7.3 (> 75% of yellowing of leaves and legumes), R8.1 (50% defoliation) (Ritchie *et al*., 1982 adapted by Câmara, 2006) and a control without application.

The soybean cultivar used was the FPS URANO RR (Fundação Pró Sementes) having maturity group 6.2, early cycle, determinate growth habit. Sowing of soybean was held on November 28, 2014, under no-tillage system with spacing of 0.45 m between lines. The experimental plots had dimensions of 7.0 x 3.6 m, and evaluations were carried out in 6-axis portion, excluding 1.0 m at the ends of lines, thus resulting in a floor area of 13.5 m². Seed treatment was performed using the insecticide Fipronil + base fungicide base pyraclostrobin + fludioxonil, and fertilizer basic cobalt and molybdenum. The basic fertilization at sowing was 210 kg ha^{-1} of triple superphosphate, and about thirty days after, broadcast application of 160 kg ha^{-1} of potassium chloride; Both following the recommendations for the cultivation according to soil analysis and official recommendations of fertilization and liming adopted in the states of Rio Grande do Sul and Santa Catarina (CQFS-RS/SC 2004). During the experiment, all phytosanitary managements followed the recommendation of the technical bulletin for culture. The desiccant herbicide used was paraquat at a dose of 480 g a.i. ha^{-1}. The treatments were applied using a pressurized CO_2 sprayer at 200 kPa pressure and 200 L ha^{-1} spray volume. The harvest was carried out in floor area of 13.5 m², with the treatments harvested at different times according to the desiccation period and ideal harvesting point. The variables analyzed were: a) number of days in advance of the harvest: determined by the cycle difference (planting to harvest) among the plots that received application of desiccant and control (without desiccant); b) thousand grains weight c) grain yield: sampling of the entire floor area was carried out, with subsequent mechanical track. After mechanical track, was made to clean the samples, weighing, determination of moisture and correction weight to 13% humidity. At this moment it was performed to evaluate the weight of 1,000 grains weight according to the methodology described by RAS (Brasil, 2009).

The second stage of the work was carried out at the Seed Technology Laboratory of Federal University of Santa Maria, Campus Frederico Westphalen- RS to determine the physiological seed quality. The seeds of evaluations were performed according to the criteria of the RAS (BRASIL, 2009) and the variables were analyzed: a) first count (FC), held on the fifth day after start of the test, taking into account the issue of the aerial part of the radicle; b) germination (G): performed by counting the number of seeds that perfectly issued shoot and radicle, evaluated the eighth day after the start of the test; c) normal seedlings (NS): held by counting normal seeds, which have well-developed root system and shoots, namely those seedlings that have the potential to continue their development and give rise to normal plants; d) abnormal seedlings (AS): held by counting abnormal seeds as those which did not show potential for further development and give rise to normal plants. Are plants which do not root system and / or well-developed aerial part. Data were submitted to analysis of variance (ANOVA), and there significance, the treatments were compared by Tukey test at 5% probability.

RESULTS AND DISCUSSION

Soybean pre-harvest desiccation with herbicide paraquat allows early harvest between four and nine days before the control (without desiccation), depending on the developmental stage in which soybean was at the time of desiccation (Table 1). These results go against those presented by Lacerda *et al*., (2001), where the application of herbicides paraquat and diquat anticipated harvest in seven days. In 2011/12, Pereira *et al*., (2015) observed anticipation six days in the harvest with the use of glufosinate ammonium and paraquat as desiccants applied at R7.1 stage and maintain seed quality. Using herbicides diquat and paraquat in soybean desiccation in R6.5 and R7 stages, Daltro *et al*., (2010) observed early harvest only two days regarding the witness without desiccation, this observation similar to Kappes *et al*. (2009). In the season 2012/13, Pereira *et al*., (2015), report that there was no anticipation of the harvest with desiccation and justification authors that is associated with the occurrence of rain in harvest pre Furthermore, the authors state that desiccation this condition did not affect the physiological quality of seeds. The trend is that the later is the lowest desiccation will be the days in anticipation of the harvest; it was also evident in the work of Coelho *et al*., (2013) which concluded that desiccated at R7 and R8 stage resulted in anticipation of the harvest. Remember

that the difference in days between the desiccation and soybean harvest observed in studies in the literature may be associated with the time of that application, the product dose and climatic conditions during and after application of the desiccant.

Table 1. Days earlier harvesting of soybean, cv. FPS Urano RR, with application of paraquat as desiccant (400 g ai ha-1) at different stages of soybean desiccation

Desiccation stages	Harvest DAS[2]	Harvest date	Days in advance
R7.1	117	25/03/2015	9
R7.2	119	27/03/2015	7
R7.3	121	29/03/2015	5
R8.1	122	30/03/2015	4
Control[11]	126	03/04/2015	0

[1] No desiccant herbicide application.
[2] Days after sowing.

Table 2. Thousand seed weight (TSW) and grain yield of soybean cv. FPS Urano RR upon application of paraquat desiccant (400 g.I ha^{-1}) in various desiccation stages

Desiccation stages	PMS (g)	Grain yield (kg ha^{-1})
R7.1	138.100 c[3]	4.169,88 b
R7.2	140.175 bc	4.211,82 b
R7.3	141.975 bc	4.241,22 ab
R8.1	144.575 ab	4.407,24 ab
Control[1]	148.075 a	4.495,02 a
CV[2] (%)	1.69	2,77

[1] No desiccant herbicide application.
[2] Coefficient of variation.
[3] Means followed by identical letters in columns, do not differ by Tukey test at 5% probability.

Table 3. First count (FC), germination (G), normal seedlings (NS) and abnormal seedlings (AS) of soybean cv. SPF RR Urano under paraquat application effect desiccant (400 g. I ha-1) in various desiccation stages

Desiccation stages	FC (%)	G (%)	N S(%)	AS (%)
R7.1	87.50 a[3]	89.75 a	84.00 a	5.75 a
R7.2	88.50 a	91.00 a	85.50 a	5.50 a
R7.3	94.25 a	94.50 a	91.25 a	3.25 a
R8.1	92.20 a	93.00 a	87.00 a	6.00 a
Control[1]	88.00 a	90.25 a	84.00 a	6.25 a
CV[2] (%)	5.49	3.76	4.06	4.63

[1] No desiccant herbicide application.
[2] Coefficient of variation.
[3] Means followed by identical letters in columns, do not differ by Tukey test at 5% probability.

The thousand seed weight of soybeans was reduced as was the anticipation of desiccation before the harvest, causing significant damage to thousand seed weight of soybeans in the first three application stages (R7.1, R7.2 and R7.3) being observed a 4.4 to 6.7% compared to control (Table 2). In the stage R8.1 does not differ from the control, and herbicide application in R7.2 and R7.3 stages. These results are similar to those found by Lamego *et al*., (2013), which found that the application of soy pre harvest desiccant from R7.3 stage caused damage to t thousand seed weight of soybean. Results weight of thousand grains were higher than the control because rain has not occurred between the desiccation and Crop differently placed Inoue *et al*., (2012), observed that where rainfall after desiccation reduces weight thousand grains. ture, thousand grains weight is the component that most explains the grain yield, as at the time of herbicide application before the harvest of soybeans, the vegetative part of the culture now is all developed and only the weight of grain is affected, thus, showed a high positive correlation between productivity and 1,000 grains weight of soybean (Pearson r = 0.97). Thus, the lowest PMS observed in R7.1 and R7.2 justify lower productivity in these two times compared to the control (Table 2). The application of paraquat in R7.1 and R7.2 stages significantly reduced soybean grain yield compared to control at 7.2% and 6.3%, respectively (Table 2). However, the application of desiccant in R7.3 and R8.1 stage did not significantly reduce productivity, but numerically it was 5.6 and 1.95%, respectively compared to control. This shows that even not statistically different, desiccation of soybean in later stages has the potential to cause reduction of grain yield. According Pelúzzio (2008) that can be associated with the fact that the plant still translocating assimilates to seed, occurring desiccation a standstill of supply and consequently decreased productivity, even by that even in R8.1 stage vegetables are still filling grain, since it is not uniform in the plant. Within this same line of study, Lamego *et al*., (2013) found a 13% reduction in soybean grain yield with desiccation held at R7.1 stage, increasing this percentage to 35% when this practice occurred in the R6 stage.

Moreover, Inoue *et al*., (2012), found no application in the treatment of desiccant, the worst result in the productivity, mainly due to the occurrence of rain at the time of the soybean crop. Thus, in cases where systems have high rainfall at harvest, pre harvest desiccant is an important management to avoid loss in productivity. The physiological quality of soybean seeds was not influenced by desiccation treatments compared to the control (Table 3). Although there was no significant difference in the first count germination (FCG) for the various stages of application of paraquat, the highest percentage of germination in the first count was observed with application of paraquat at R7.3 stage. This is consistent with the results obtained by Kappes *et al*., (2009), where evaluating germination index reach the conclusion that the best time to soybean desiccation seeking greater germination percentage is the R7.3 stage. The first count evaluated germination on the fifth day is taken as indicative of vigor lot, influencing the emergence and establishment of plants in the field. Although not significantly different, the results show that the soybean desiccation at R7.3 stage was presented the most indicative of force, followed by R8.1 stage, R7.2, witness and R 7.1, respectively. As for the percentage of germination, all treatments show higher values than required in the national standard germination (80%) (Abrasem, 2013) (Table 3).

The best treatments were those with application of paraquat in R7.3 and R8.1 stage compared to control (without application of paraquat). Already the germination percentage with desiccation at R7.1 stage was presented the lowest germination even if not differ significantly from the other treatments. Similar results were obtained by Kappes *et al*., (2009), where desiccant applications R6, R7.1 and R7.2 cause significant losses for seed germination when compared to control. Paraquat applications in R6 stage reduced the physiological quality when compared to the application in the R7 and R8

stage with the greatest percentage of germination, accelerated aging, root length and electrical conductivity (Marcandalli *et al*., 2011). Veiga *et al*., (2007), consider that the germination potential of seeds increases with the natural loss of water in the field. In his work he concludes that seed harvested in R7stage have superior physiological quality harvested in R6 stage. With the use of the herbicide diquat, Inoue *et al*. (2012) achieved similar results, where the analysis germination concluded that the application of the reproductive stage R7.5 (pods 90% yellow) show the best results because they have already reached physiological maturity. The authors also state that on average the lowest values in the germination percentage were observed in treatments without desiccation.

When analyzed variables normal and abnormal seedlings, it is observed that there was no significant difference between the treatments (Table 3). But in desiccation at R7.3 stage is observed the highest germination rates, thus, a higher percentage of normal seedlings and a lower percentage of abnormal seedlings, making it clear that the soybean desiccation thinking early harvest should be made from the R7.3 stage.

Conclusions

The soybean crop is anticipated nine to four days when it is performed the management of preharvest desiccant paraquat, when the plant is among the top 50% of yellowing of leaves and fruits (R7.1) and beginning 50 % defoliation (R8.1). The management of pre-harvest desiccation with paraquat does not affect the physiological quality of soybean seeds from the stage between start 50% of yellowing of leaves and vegetables (R7.1). Soybean yield is not affected when the management of pre-harvest desiccation with paraquat is performed when the plants have more than 75% of yellowed leaves and vegetables (R7.3).

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