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Scientific paper

Anticipation of soybean harvest by chemical desiccants

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Abstract

The study was developed with the objective of studying the optimal moment for the applliccation of desiccant herbicides, the feasibility of early harvesting and its effects on the yield and physiological quality of soybean seeds. The research was conducted in the Vovó Palmira Farm, in Jardim Olinda PR Brazil. It was used the Cultivar BMX Potency RR sown during the normal growing season. The experimental design consisted of randomized blocks in a 5 x 11 factorial scheme, during five application periods, with doses of the herbicides Paraquat and Diquat (2000 ml ha^{-1}) and control. The results showed that the Paraquat has more homogeneous parameters in its applications, whereas the Diquat of 3 and 6 days provided the best results, being that with an increase in the number of days occurs a decrease in weight and an increase in moisture rates, showing low quality and high drying time. The areas in which the pesticides were applied failed to be appropriate for certified seed banks, due to the moisture rates and also the quantity of dead and abnormal germinations. However, they were effective in the reduction of the plant's dry weight and in the improvement of the harvest process.

Keywords: herbicides, anticipation, harvest, germination.

Antecipação da colheita da soja por meio do uso de dessecantes químicos

Resumo

O estudo foi desenvolvido com o objetivo de estudar o momento ideal para a aplicação de herbicidas dessecantes, a viabilidade da antecipação da colheita e seus efeitos sobre o rendimento e a qualidade fisiológica de sementes de soja. A pesquisa foi instalada no Sítio vovó Palmira, em Jardim Olinda – PR. Utilizou-se o Cultivar BMX Potência RR semeada na safra normal. O delineamento experimental foi o de blocos casualizados em esquema fatorial 5 x 11, sendo cinco épocas de aplicação combinadas com doses de herbicidas dessecantes Paraquat e Diquat (2000 ml ha-1) e testemunha. Os resultados mostraram que Paraquat tem parâmetros mais homogêneos em suas aplicações, enquanto o Diquat de 03 e 06 dias tem os melhores resultados sobre a cultura, sendo que com o aumento na quantidade de dias ocorre um decréscimo no peso e um acréscimo no teor de umidade, mostrando baixa qualidade e gerando maior tempo de secagem. Áreas em que foram aplicados os agroquímicos não podem servir como banco de sementes certificadas, devido ao teor de umidade e também a quantidade de germinações anormais e mortas, mas mostraram-se eficientes na diminuição de matéria seca das plantas, assim melhorando o processo de colheita.

Palavras-chave: herbicidas, antecipação, colheita, germinação

Anticipación de la cosecha de soja mediante el uso de desecantes químicos

Resumen

El estudio fue desarrollado con el objetivo de estudiar el momento ideal de aplicación de desecantes, la viabilidad de la anticipación de la cosecha y sus efectos sobre el rendimiento y calidad de semilla de soja. La investigación fue instalada en el sitio Abuela Palmira, Jardín Olinda - PR. Se utilizó la cultivar BMX Potência RR sembrada en ciclo normal. El diseño experimental fue de bloques al azar en factorial 5 x 11, con cinco épocas de aplicación combinada con doce dosis de herbicidas desecantes Paraquat y diquat (2000 ml ha^{-1}) y el testigo. Los resultados mostraron que el paraquat tiene parámetros más homogéneos en sus aplicaciones, mientras con el aumento en la cantidad de días ocurre un una disminución del peso y un aumento en el contenido de humedad, que muestra una menor calidad y genera un mayor tiempo para el secado. Las áreas que se han aplicado los productos agroquímicos no pueden servir como banco de semilla certificada debido al contenido de humedad de las semillas y también que presentan cantidad de germinación anormal y mortalidad, pero fueron eficaces en la disminución de la materia seca de la planta, mejorando así el proceso de recolección.

Palabras clave: herbicidas, anticipación, cosecha, germinación.

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Introduction

Soybean (*Glycine max*) is natural to China's eastern region and developed some 5000 years ago, with domestication around the 11th century CE. The first register for the introduction of soybean in Brazil dates from 1882 Bahia by Gustavo Dutra. Several other historical entries state that the 'yellow' soybean was initially planted in the Campinas Agronomic Farm in 1891 as a forage plant and introduced in the state of Rio Grande do Sul in 1900. The culture's expansion phase occurred in 1936 and was reported in official government statistics in 1941. The 1960s saw a swift development of soybean culture favored by the corn infrastructure which was idle during the hot season. A leguminous plant had to be found for corn succession. Soybean plant and its perfect adaptation to the system warranted its increasing participation in the agriculture of the most southern state of Brazil. During the 1961-1965 period, Rio Grande do Sul produced 90% of the Brazilian soybean production. As from 1976 Rio Grande do Sul and Paraná contributed equally in the soybean production in Brazil (FUNDAÇÃO CARGILL, 2009). Therefore, as from the 1970s, the culture of soybeans developed significantly in the producing states in southern Brazil and also in the states of the Brazilian mid-western region. Through the development of new cultivars adapted to different agro-climatic regions of Brazil, the country became the second world producer of soybeans (BIODIESELBR.COM, 2009).

The mature pod on the main stalk, or rather, Stage R7, indicates physiological maturity for the plant and plant population (LACERDA *et al.* 2003). Grain yield is thereby determined due that plants have reached their highest dry matter accumulation. However, no difficulty exists for the characterization of Stage R8 (MANICA and COSTA, 1996).

After its physiological maturity, the seed may be stored on the field even though the harvest had not taken place. If climate conditions are favorable between physiological maturity and the normal harvest period, deterioration problems are greatly lessened. However, if significant rainfall, oscillations in relative air humidity and temperature variations occur during the maturation period, high losses in the physiological and pathological quality of the seeds will be reported. Infestation by bugs is another factor that, coupled to other mechanical damages during harvest, contributes towards the significant waste of a great number of seeds (COSTA et al, 1982).

After the seeds have reached physiological maturity in which no dry matter accumulation takes place, and humidity reached approximately 50%, the harvest may be theoretically undertaken. However, the plants are still not adequate for the harvest. Since many green leaves are extant and the stalk and branches are still full of sap, it is impossible to use harvesting machinery (INOUE *et al.*, 2003).

During the seed maturation process, several morpho-physiological and functional changes occur starting from maturation of the ovule, which continue up to the point that the seeds are ready for harvest. Changes in dry matter, water quality, size, germination and potency of the seeds are verified mainly during this period. Biochemical modifications may also be observed (MIGUEL, 2003).

After physiological maturity, the storing of seeds on the field is decisive for their deterioration or loss of potency, coupled to environmental conditions during the maturation phase that also affects the physiological quality (CARVALHO and NAKAGAWA, 2000).

However, if high rainfall rates, fluctuations of relative air humidity and great variations in environmental temperature occur during the maturation period, great losses in physiological and pathological qualities of the seed produced will occur. DELOUCHE et al. (1973) report that the deterioration of seeds on the field during the physiological maturity and harvest is determined by genetic factors and environmental conditions (temperature, rainfall and relative humidity).

It would be highly interesting that seed harvest is undertaken as near as possible to the physiological maturity period when the humidity rate is close to 25%. However, high humidity rates associated to the great quantity of green leaves and stalks make mechanical harvesting impossible. A solution for such a difficulty is the application of leaf desiccants. If such practice brings about satisfactory results, it may contribute towards an increase in the number of quality seeds.

DURIGAN (1979) studied the application of Paraquat as from 72 and 75 days after the start of flowering of the cultivars IAC-2 and Santa Rosa, respectively. After several germination and potency tests, the author concluded that seeds from desiccated plants were always superior in germination and potency even though not significantly higher than those of plant seeds with no desiccants. The same author also reported that seeds from desiccated plants had a lower rate of pathogen fungi.

On the other hand, the same study detected residue wastes of Paraquat in the seeds and, in his opinion, crops with Paraquat applications should never be provided for human intake. METCALFE *et aI*. (1956) and BOVEY *et al*. (1969) also showed that among the several disadvantages of the desiccation procedures, residues in the harvested material and fall in seed germination which depend on the chemical product and doses used, are the most relevant. BASTIDAS *et al*. (1971) tested several products for soybean culture and verified that Paraquat at doses 0.36 and 0.48kg i.a. ha^{-1} provided an early harvest between 10 and 15 days. The same authors also observed that chemical analysis revealed total absence of chemical residues in the seeds.

Owing to high moisture rates at the highest weight of dry matter (30 – 50%), the seeds are highly susceptible to mechanical damage by crushing which may be more dangerous than losses since the former is not visible and may not modify greatly the physical characteristics of the seed. Its elimination occurs during industrial processing. Another important issue is that if seeds are harvested with high moisture rates, pure seeds may undergo within 2 to 3 days a drastic process of deterioration with their eventual non-utilization for seeding (CARVALHO; NAKAGAWA, 2000).

It is important to note that desiccation may not be routinely practiced. If it is required, the exact moment for application should be taken into account. Desiccation is indicated at the plant's physiological maturity stage or R7. This occurs when at least one pod on the main stalk is mature and the others are green or yellowish. The soybean plant starts to lose its deep green color in these conditions. Desiccant applications prior to the culture's physiological maturity stage may interfere in grain filling and increase the possibilities of deficiencies in greenish grains. In fact, they are factors that may lead towards loss in yield and quality of the final product. Further, if it rains after application of desiccant, an increase in deteriorated grains by fungus may occur. Another important factor that farmers have to comply with is the desiccant's compulsory threshold period. At least seven days are required after the application of the product so that harvest would start. If the threshold period is not complied with, grains will have more product residues than allowed.

Quality decrease may be perceived by a decrease in germination and potency triggered by a rapid deterioration process through the crushing and compression of tegument cells because of absorption cycles and moisture loss that cause rapid and differential contractions of the tissues. Industrial quality is also decreased (and, consequently, the product's price) due to the low weight per hectoliter and by the extracted oil with high rates of free fatty acids (MANICA and COSTA, 1996).

Germination is basic when culture aims at seed production. Harvest period, moisture rates of seeds at harvest time and care in the harvest aftermath such as transport, drying, industrial processing and storage are important and determining stages for high performance seed production.

According to NETO et al. (2007), when the area is chosen for seed production, seeds are normally harvested when moisture contents for the first time reach rates close to or below 15% during the natural drying process on the field. Harvest acceleration or delay will result in germination and potency decrease and an increase in infection by field pathogens. Paraquat, the commercial name for Gramoxone 200 and 1,1'-dimethyl-4,4'-bipyridinium-dichloride ($C_{12}H_{14}Cl_2N_2$) according to IUPAC nomenclature, is a non selective herbicide of the quaternary ammonium herbicide family. It is used as an herbicide, albeit highly dangerous for people when taken. The crystalline solid compound is unstable in alkaline medium, soluble in water and slightly soluble in alcohol but insoluble in non-polar organic solvents. The product is corrosive to metals and incompatible with humidification alkylarylsulfonate wetting agents. However, it is stable in acid or neutral solutions but quickly hydrolyzed by alkali bases.

Paraquat action focuses on the presence of light and dehydrates the green parts of the plants with which it makes contacts. After application, the penetration by the leaf surface is almost immediate. Absorption is increased by high light intensity and by the specific adjuvant system. The addition of adjuvants to the mixture of the tank is required if this is not part of the formula.

Diquat, commercial name of Reglone and 9, 10-dihydro-8a, 10a-diazoniaphenanthrene according to IUPAC nomenclature, is a wide spectrum herbicide which belongs to the bipyridinium chemical group. Its mechanism works through the capture of electrons from photosynthesis and respiration, with free radicals, which result in the formation of hydroxyl radicals and free oxygen (singlet), which trigger the peroxydation of lipids of the cell membranes and discharge of cell juice and tissue death.

Diquat is soluble in water but deactivated when in contact with soil through a complete adsorption of the cation in the clay. Leaching is therefore nil and microbial decomposition in the soil is very slow. Owing to the high adsorption of Diquat by soil colloids, the use of dirty water, with excessive clay suspension, should be avoided for the application of this herbicide. Otherwise, loss of treatment efficiency occurs.

Current assay studies the efficiency of desiccants, the ideal time for their application, their feasibility in early harvest, their effects on yield and the physiological quality of seed.

Materials and methods

Although not recommended for the western region of the state of São Paulo, Brazil, the cultivar Potência RR is employed. The latter is close to the cultivar Conquista, currently recommended and used by farmers in the region.

Current experiment was carried out on the Vovó Palmira farm (Latitude: 20º 03′ 05″; Longitude: 51º 48′ 36″) in the municipality of Jardim Olinda PR Brazil, and in the Laboratory of Seed Analysis of the Agrarian Sciences Faculty of the Universidade do Oeste Paulista (UNOESTE), between November 2010 and March 2011. Evaluations on productivity and physiological quality of the seeds were undertaken immediately after harvest.

The experiment was performed in Red-Yellow Argisol of the sand phase (EMBRAPA, 1999) and the soil's chemical and physical characteristics were determined by the Laboratory of Soil and Vegetal Tissue Analysis of the Universidade do Oeste Paulista (UNOESTE) from the samples provided.

Basic fertilization with an expected yield of 2700 kg.ha^{-1} was calculated according to the results of chemical analyses. Basic fertilization consisted of 300 kg.ha^{-1} of the formula 02 – 30 – 10 (06 kg N, 90 kg P_2O_5, 30 kg K_2O).

Herbicide dose consisted of a single dose of 2 liters of the active chemical agent in broth per hectare of the two herbicides Paraquat and Diquat. Application periods of herbicides were according to physiological maturation, or rather, some days after R5. They were performed by shoulder constant pressure sprayer.

Separation in sieves consisted of about 300g of previously weighed seeds for treatment and repetition, classified in circular screen sieves. Amounts retained in each sieve (18, 17, 15, 13 and bottom, with screen measuring 0.71, 0.67, 0.59, 0.51cm and bottom, respectively) were again weighed to calculate the retention percentage in the sieves.

Eight sub-samples of 100 seeds were separated to determine their mass by replication of each treatment of the retained portion in sieve 15. Their mass was determined by a hundredth gram sensitive scale, following prescription by Rules for Seed Analysis (BRASIL, 2009).

Amount of green grains was determined in each sub-sample of 100 seeds used to determine mass described in 4.9. Green grains were separated from the yellow ones, counted and weighed to calculate the percentage of green grains.

Germination test was performed with four 50-seed sub-samples by repeating each treatment, in Germitest paper napkins, in a germinator gauged at 25ºC. The amount of added water was 2.5 times the weight of the dry sub-stratum, so that adequate moisture and therefore test uniformity could be achieved. Counts on the 4th and 7th day after seeding followed criteria by Rules for Seed Analysis (BRASIL, 2009). Results were given in percentage.

The experimental design comprises randomized blocks with four repetitions within a 2 x 5 factorial scheme, or rather, two herbicides were applied at 5 different periods, totally 10 treatments with 5 repetitions, within a total of 50 plots (Table 5).

The plot as an experimental unit consisted of 5 lines 5.5 m long.

Usage area to determine seed yield and quality comprised 3 central lines, with borders of 1 line for each side of the central area and 0.5 m for each extremity.

Results and discussion

Figure 1 shows that, when compared to rates of control, Gramoxone 3 and 6 days and Reglone 3 and 6 days had the same production in the planted area, but revealed significant losses when applied on the 15th day.

The equation of the straight line for Reglone was $y = 0.8112 - 0.0012X - 0.0007X^2$ and $R^2 = 0.9238$, where x is the days of application and y the weight of the seeds harvested in one ha. R^2 shows that the model explains the equation. In the case of Gramoxone, the equation was $y = 0.812 - 0.002X - 0.0006X^2$ and $R^2 = 0.9613$.

When the Brazilian and Paraná state harvests for the last 10 years were compared, respectively 3.54 tons and 2.31 tons per ha (DERAL 2010), Gramoxone and Reglone 3 and 6 days were higher to the national and the state of Paraná averages. The above facts show a better production per ha when Gramoxone and Reglone are employed as desiccators.

Figure 2 shows the moisture of seeds harvested and the Figure 3 shows that rates do not differ in the number of pods per plant and demonstrates a difference in seed amount per pod.

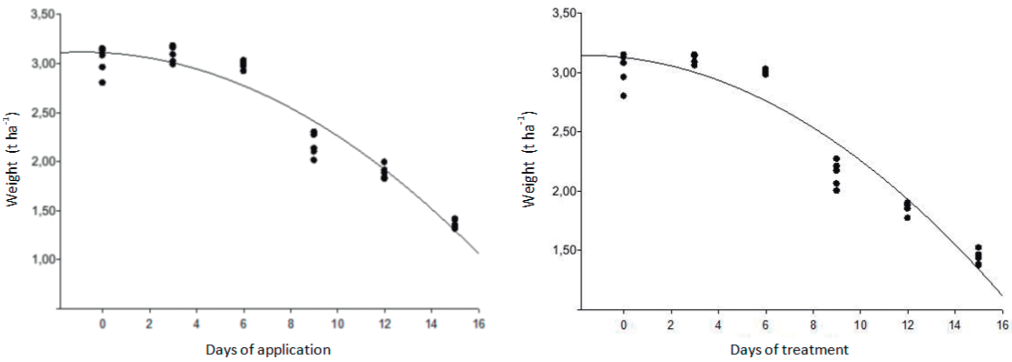

Figure 1. Mean weight (in tons per ha) of seeds harvested in the plots, by Tukey's test at 0.05 probability.

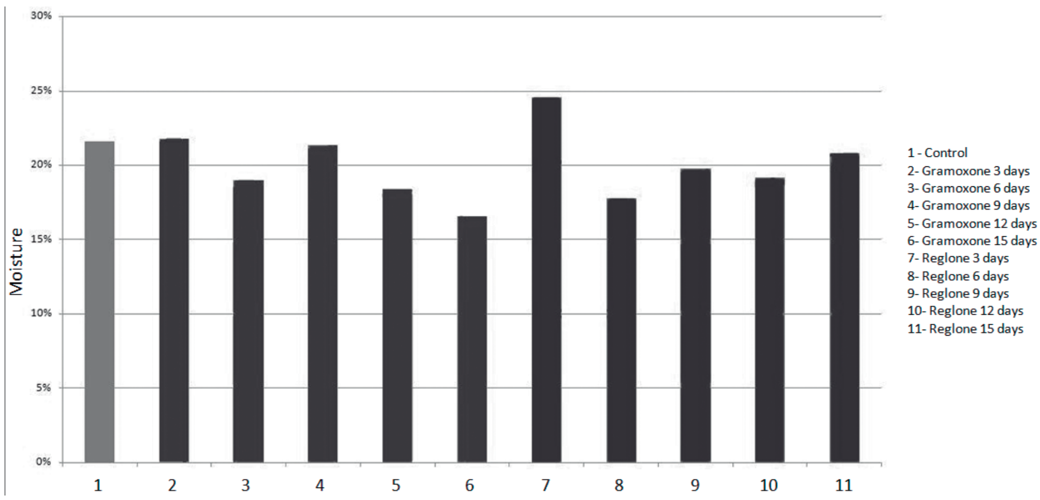

Figure 2. Moisture of seeds harvested in the plots (Tukey's test at 5% probability)

Figure 4 shows that Gramoxone 3, 9 and 15 days had better results on high potency seed germination when compared to those of control. In the case of weak potency seeds, Gramoxone 12 days and Reglone 9 and 3 days had better results, whereas Gramoxone 6 and 12 days and Reglone 3, 9 and 15 days had the best results for abnormal and dead seeds. However, these applications would not be recommended for seed fields due to the quantity of abnormal and dead plants germinated.

Table 9 shows that no sample achieves minimum germination for the seed producing area. EMBRAPA Soybean's basic standard in its production system guidelines lies at 75% with a 10% tolerance under or above. In fact, only Reglone 6 days comes close to this percentage.

It may be observed that the highest dry matter rates of the aerial sector form the control, followed by Gramoxone 3, 9 and 6 days, whereas the lowest rates were obtained by Gramoxone 12 and 15 days and by Reglone 6 and 15 days. In fact, these are mostly recommended for harvesting with inferior-conditioned machines. This is due to a low efficiency of the apparatuses. On the other hand, in a no-tillage system only a small quantity of culture wastes are extant for soil protection.

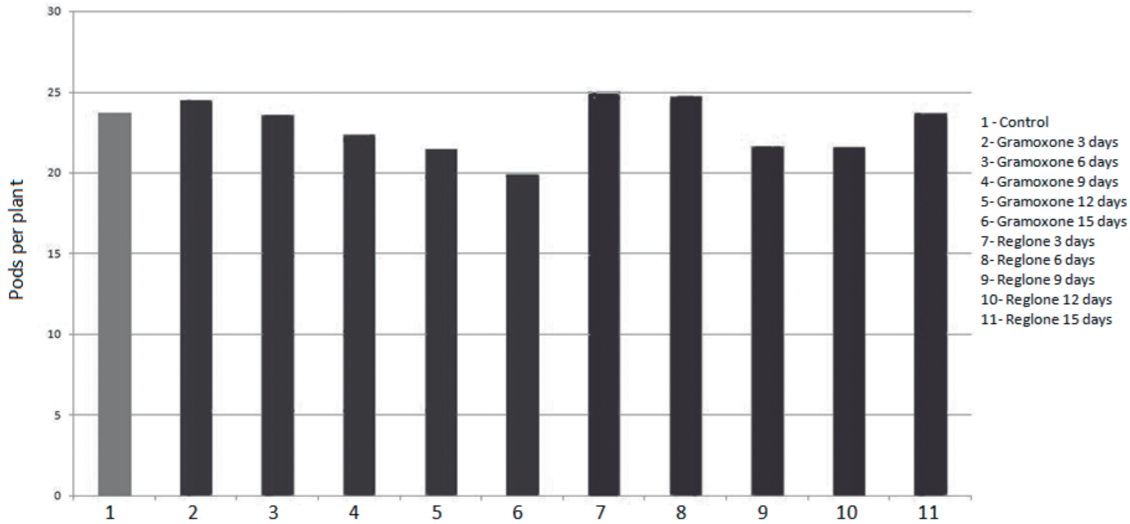

Figure 3. Amount of pods per plants in the plots (Tukey's test at 5% probability).

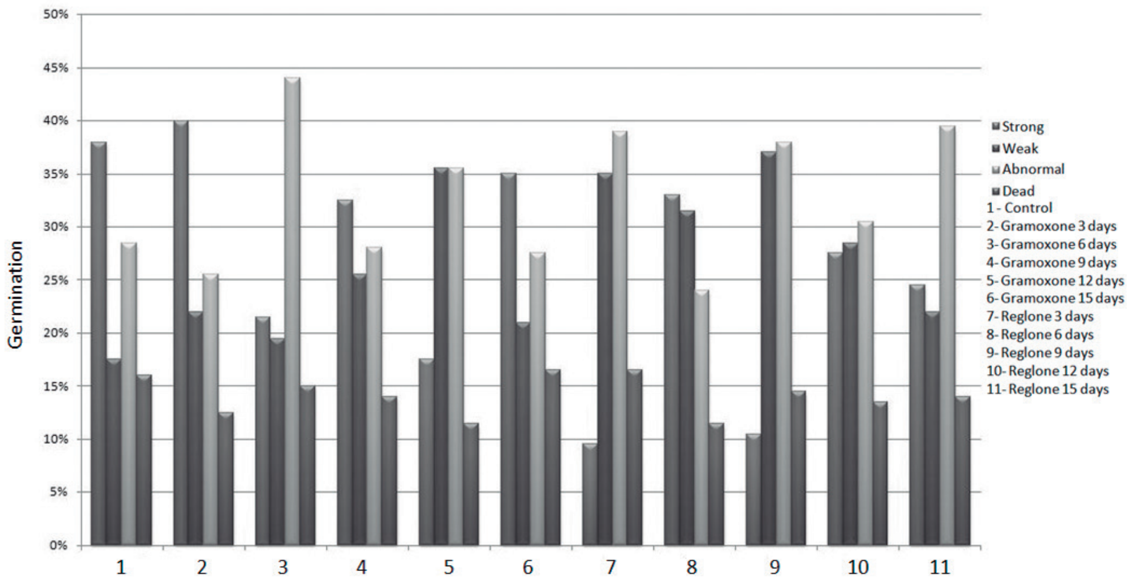

Figure 4 . Percentage of germination types of harvested seeds

Figure 6 demonstrates that in the case of Gramoxone 15 days the weight of 100 seeds is lower when compared to that of other applications. The plant may have employed photo-assimilated factors retrieved from soybean grains for its own protection.

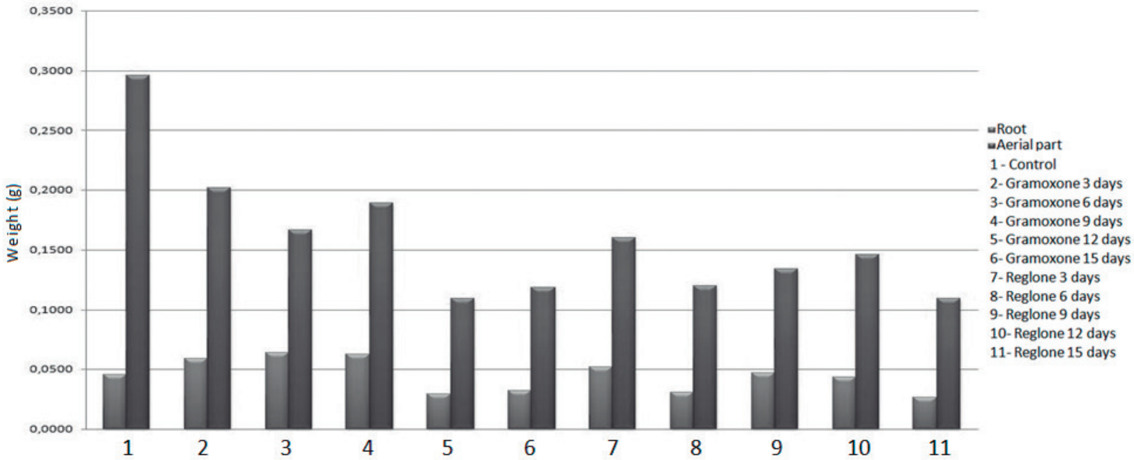

Figure 5. Dry matter from the germination of harvested seeds

According to EMBRAPA Soybean, a 60k sack of soybeans may produce an average of 8L of oil and 52kg of meal and other small rates of residues (lecithin, hexane and soaps). Therefore, there is a production of 1.33 mL of oil and 8.66 g of meal for each 10g of seeds. Gramoxone 15 days, therefore, had the worst performance for the production of the main products derived from soybean grains.

Figure 7 reveals that most seeds in treatments and control were retained in sieve 16 and only Gramoxone 15 days provided the highest retentions in sieves 15, 14 and 13.

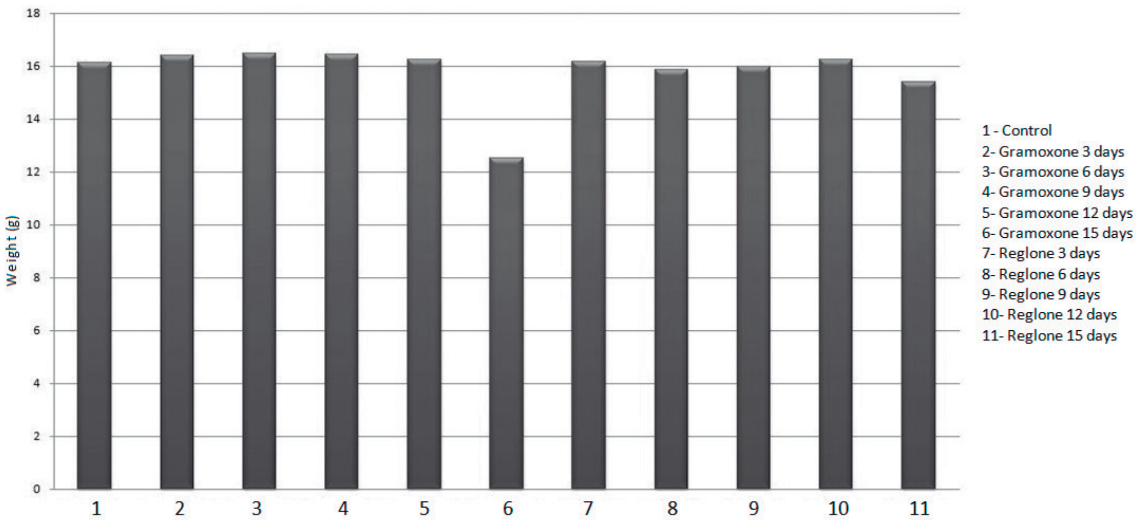

Figure 6. Weight of 100 harvested seeds

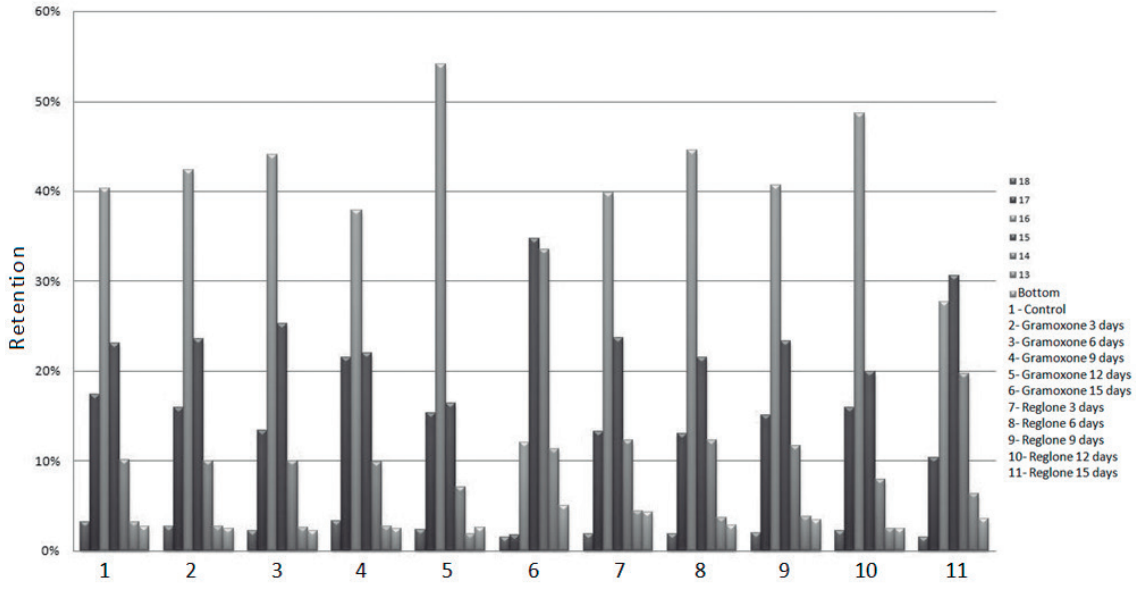

Figure 7. Retention percentage of collected seeds in sieves

Conclusions

Data analyses and interpretation of results produce the following conclusions:

- In field data Gramoxone has data that are more homogeneous in its application, whereas Reglone 3 and 6 days reveal the best results.

- Field data show that, in the case of Reglone, as the number of days increases, there is a decrease in weight and an increase in moisture rates, with low quality and high drying time.

- Areas in which Paraquat, such as Diquat, was employed, are not appropriate as a bank for certified seeds, due to moisture rates and to the number of abnormal and dead germinations.

- Products applied at 12 and 15 days were efficient in decreasing the plants' dry matter and in the improvement of the harvest process.

- Only Gramoxone 15 days caused a significant decrease in the weight of 100 seeds, probably due to the use of photo-assimilates by the plant.

- Homogeneity in sieve 16 and only with Gramoxone 15 days was observed, albeit with lower rates in this type of sieve. Higher and above average rates were observed in sieves 15 and 14, followed by Reglone 15 days. In this case, the smallest the grains, the greater was the density per m^3. This was due to the small size of the porous area that makes difficult later drying.

- With regard to purity, the best results were obtained by Gramoxone and Reglone 15 days; this was probably due to desiccation of weeds and loss of leaves from the soybean plants.

- Moisture percentage in seeds which were harvested and taken to the laboratory shows that Gramoxone 6 days had the best results, followed by Gramoxone 9 days and Reglone 3 and 6 days.

- It should be emphasized that rainfall during this period was higher than normal and may have caused alterations at harvest time.

- It may be concluded that Gramoxone and Reglone produced good results in soybean desiccation, especially between 6 and 15 days with Gramoxone and between 12 and 15 days with Reglone.

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