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Viability and vigor of soybean seeds as a result of industrial seed treatment and stored in different environments

Viabilidade e vigor de sementes de soja em função do tratamento industrial de sementes e armazenadas em diferentes ambientes

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Highlights

Chemical treatment and storage time can negatively influence soybean germination.
The storage of treated seeds in a cold chamber greater viability of soybean seeds.
Cold chamber storage maintains the quality of treated soybean seeds.

Abstract

The industrial seed treatment (IST) of soybeans is an economically recommended technique in agricultural production, providing protection against pests and initial pathogens. However, the real effects of pesticides about the quality of soybean seeds are still little known, since the adoption of the system is still recent by soybean farmers. The objective of this work was to evaluate the physiological quality of soybean seeds, treated or not, with insecticide/ fungicide new mixtures and stored for 240 days in a non-controlled and controlled environment. The completely randomized design was used, distributed in a 5 x 2 x 6 factorial scheme with four replications. The plot treatments consisted of soybean seeds belonging to the cultivar M - 7739 IPRO, treated with six different insecticide/ fungicide mixtures {(Cruiser®); (Amulet®); (MaximAdvanced®); (Cruiser®+ MaximAdvanced®); (MaximAdvanced® + Amulet®); (untreated control)}, stored in two environments {(laboratory – without control and cold room – with control (10 ± 2 ºC,45± 2% UR)} for eight months of storage with five evaluation times (0; 60; 120; 180 and 240days). The following

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tests were carried out: water content, germination, first count, seedling length and seedling dry mass. It was found that the chemical treatments negatively affect the germination potential of seeds, especially after 120 days of storage, regardless of the environment.Thiamethoxamand Thiamethoxam + Metalaxil; Tabendazole; Fludioxonil after storage provided the biggest reductions in seed viability and vigor after 240 days of storage. The cold room environment provides better conditions for the conservation of the germinative potential of soybean seeds.
Key words: *Glycine max.* Seed treatment. Seedquality. Viability and vigor. Storage.

Resumo

O tratamento industrial de sementes (TIS) de soja é uma técnica economicamente recomendada na produção agrícola, proporcionando proteção contra pragas e patógenos iniciais. No entanto, os reais efeitos dos agrotóxicos sobre a qualidade das sementes de soja ainda são pouco conhecidos, visto que a adoção do sistema ainda é recente pelos sojicultores. Objetivou-se com este trabalho avaliar a qualidade fisiológica das sementes de soja, tratadas ou não, com novas misturas de inseticidas/fungicidas, e armazenadas por 240 dias, em diferentes ambientes. O delineamento experimental utilizado foi inteiramente casualizado, distribuído em esquema fatorial 5 x 2 x 6, com quatro repetições. Os tratamentos das parcelas foram constituídos de sementes de soja pertencentes à cultivar M – 7739 IPRO, tratadas com seis diferentes misturas produtos de inseticida/fungicida {(Cruiser® - Tiametoxam – 200 mL + Bio Cromo – 100 mL); (Amulet® - Fipronil - 100 mL + Bio Cromo – 100 mL); (MaximAdvanced® - Metalaxil-M; Tabendazol; Fludioxonil – 100 mL + Bio Cromo – 100 mL); (Cruiser® - Tiametoxam – 200 mL + MaximAdvanced® - Metalaxil-M; Tiabendazol; Fludioxonil – 100 mL + Bio Cromo – 100mL); (MaximAdvanced® - Metalaxil-M; Tabendazol; Fludioxonil – 100 mL + Amulet® - Fipronil - 100 mL + BioCromo – 100mL); (controle não tradada)}, armazenadas em dois ambientes {(laboratório – sem controle e câmara fria – com controle (10 ± 2 ºC,45± 2% UR)} durante oito meses de armazenamento, com cinco tempos de avaliações (0; 60; 120; 180 e 240dias). Os seguintes testes foram realizados: teor de água, germinação, primeira contagem, comprimento das plântulas, massa seca de plântulase índice de velocidade de emergência. Verificou-se que o ambiente de câmara fria proporciona melhores condições para a conservação do potencial germinativo das sementes de soja. Os tratamentos químicos interferem negativamente no potencial germinativo das sementes, sobretudo após 120 dias de armazenamento, independente do ambiente. Tiametoxam e Tiametoxam + Metalaxil; Tabendazol; Fludioxonil após o armazenamento proporcionaram as maiores reduções da viabilidade e vigor das sementes após 240 dias de armazenamento. O ambiente de câmara fria proporciona melhores condições para a conservação do potencial germinativo das sementes de soja.
Palavras-chave: *Glycine max* [L.]. Tratamento de sementes. Qualidade de sementes. Viabilidade e vigor. Acondicionamento.

Introduction

Soybean is one of the most cultivated crops in the world, especially in the United States and Brazil, the grain has great economic importance for agribusiness and for export (Food and Agriculture Organization of the United Nations [Faostat], 2021). The growth of soybean crop in the Brazil has always been associated with scientific advancements and the availability of technologies to the productive sector, including the supply of seeds quality (Grigolo et al., 2019).

Seed production systems are sustained through the development of cultivars with characteristics of interest to farmers, seed producers and industry. In this context, in breeding programs is important to select soybean cultivars with genetic potential to ensure the vigor of the seeds in the field, even under unfavorable climatic conditions (Moreano et al., 2018). As the perception of the value of the seed increases and the importance of protecting its performance, the range of products available for seed treatment increases, with different purposes such as protection or nutrition, aiming to improve the performance of the seed, both in the physiological as well as economic aspect (Avelar et al., 2011).

The most widespread way among producers for sanitary control of seeds is chemical treatment which appears as a relevant aid to seed performance (Ludwig et al., 2015). Despite increasing the protection of seeds and assisting in the initial development of seedlings, the products used in the treatment of seeds and their mixtures should not interfere in a negative way in their physiological quality, immediately after treatment or during the storage time (Zandoná et al., 2019).

Seed producers have offered their customers the option of being treated with the combination of fungicides, insecticides, nematicides, micronutrients and polymers, among other products with high dosage precision through Industrial Seed Treatment (IST). This type of treatment has earned the space in the soybean seed market, which a large part of the companies that sell the seeds already carry out treatments in the pre-bagging before storage (Françaet al., 2015). IST emerged as a technological advance mainly due to the continued growth of cultivated areas (Peske et al., 2016).

Due to the advantages provided by IST, in the control of pests and pathogens, such as protection and improvement in the initial seedling development, it is justified to investigate the effect of the application, associated or not, of these agrochemicals by means of the referred technique, aiming to check that there is interference in the mode of action of each of them on their respective targets, nor damage to their physiological potential (Soares et al., 2019; R. C. Pereira et al., 2020).

It is also emphasized that IST is an economic and technically recommended practice, since suitable products are used, individually or in combination, in the recommended doses and uniformly distributed in all seed lots. Therefore, its use will not harm the physiology of the seeds (Peske et al., 2016). Moreover, IST faces some challenges, such as the need to estimate commercial demand, as treatment is anticipated and treated seeds that are not commercialized constitute an environmental liability, requiring proper disposal.

In cases of longer storage, phytotoxic effects of the products used on the seeds may occur in IST (T. F. Ferreira et al., 2016; Lemes et al., 2019). Thus, it is relevant to remain alert about the influence of agrochemicals about the viability and vigor of soybean seeds, considering that the results of research about the effects of seed treatments over the storage time are still incipient and not conclusive (I. L. Silva et al., 2019).

Considering that the seed storage time can extend for several months, procedures must be established to accommodate the volume received in the best possible conditions (Villela & Menezes, 2014). To work around this problem, in some cases seed producing and processing companies concentrate the treatment operation a few weeks before dispatch to the producer, because they are concerned about the harmful effects of the products about the quality of the seeds during storage (R. C. Pereira et al., 2020). However, it would facilitate logistics if this process was carried out in advance, with later storage, but for this it is necessary to know the influence of the agrochemicals used on the physiological quality of the seed during the storage time (L. G. M. Dan et al., 2010; L. C. Pereira et al., 2018; Lemes et al., 2019).

When it comes to framing batches of seeds treated in a non-controlled environment, there is relevant information for the producer that face or treatment of seeds and framing directly to its property, based on two prices of skeletons collected by the seed companies after performing two treatments to be elevated. But for this to be endowed with reliability, it is necessary to conduct studies on the viability and vigor of seeds treated and framed in a non-controlled environment.

This work aimed to evaluate the physiological quality of soybean seeds, treated or not, with insecticide / fungicide mixtures, and stored for 240 days, in a non-controlled and controlled environment.

Material and Methods

General information

Soybean cultivar M 7739 IPRO was evaluated, with an average cycle of 115 to 118 days and a semi-determined growth habit, belonging to the S2 category, originating from 6.0 sieve, produced in the 2016/2017 harvest, with 10% water content. After processing, the seeds were transported and immediately subjected to treatments and stored.

Seed treatment and storage

The seeds were treated, separated into 300gr sub-samples and packed in their respective Kraft bag packaging and packed in storage environments for eight months, with evaluations every two months, counting as zero storage time, the moment when evaluations began to be carried out.

Experimental design and treatments

The experimental design used was completely randomized, in a 5 x 2 x 6 factorial scheme, with four replications. The plots were treated with soybean seeds belonging to the cultivar M - 7739 IPRO, treated with insecticide / fungicide and polymer {(T1 – untreated control) ; (T2 -Amulet® - Fipronil - 100 mL + Bio Cromo – 100 mL);(T3 -Cruiser® - Tiametoxam – 200 mL + Bio Cromo – 100

mL); (T4 - MaximAdvanced® - Metalaxil-M; Tabendazol; Fludioxonil – 100 mL + Bio Cromo – 100 mL); (T5 - Cruiser® - Tiametoxam – 200 mL + MaximAdvanced® - Metalaxil-M; Tiabendazol; Fludioxonil – 100 mL + Bio Cromo – 100mL); (T6 -MaximAdvanced® - Metalaxil-M; Tabendazol; Fludioxonil – 100 mL + Amulet® - Fipronil - 100 mL + Bio Cromo – 100mL)} (Table 1), stored in two environments {(laboratory –without relative humidity and temperature control in a cold room – with control (10 ± 2 ºC e 45 ± 2% UR)} for eight months of storage, with five evaluation times (July/2017 a March/2018), with five evaluation times (0; 60; 120; 180 e 240 days).

The doses used to treat the seed mass were in mL according to the manufacturer's recommendation for 100 kg of seeds. After the treatments were carried out, the seeds were packed in a 80 µm thick kraft bag, being considered permeable to water vapor and gases emitted by both the seeds and those contained in the environment, allowing an exchange between the seeds and the surrounding environment.

Table 1
Commercial product, active ingredient, class of products and doses used in soybean seed treatments

Treatment Code	Commercial product	Active Ingredient (a.i)	Class of Product	Dose Product (mL 100 kg seeds)
T1	-------	-------	---------	No treatment
T2	Amulet® Bio Cromo	Fipronil	Insecticide Polymer	100 100
T3	Cruiser 350 FS® Bio Cromo	Tiametoxam	Insecticide Polymer	200 100
T4	MaximAdvanc® Bio Cromo	Metalaxil-M; Tabendazol; Fludioxonil	Fungicide Polymer	100 100
T5	Cruiser 350FS® MaximAdvanc® Bio Cromo	Tiametoxam + Metalaxil-M; Tabendazol; Fludioxonil	Insecticide Fungicide Polymer	200 100 100
T6	Amulet® MaximAdvanc® Bio Cromo	Fipronil + Metalaxil-M; Tabendazol; Fludioxonil	Insecticide Fungicide Polymer	100 100 100

Conduction of the experiment

Under cold room condition, air temperature and relative humidity of 10 ± 2ºC and 45 ± 2%, respectively, were used throughout the storage time. In an uncontrolled environment, data about temperature and relative humidity were monitored using a digital thermohygograph. With the data obtained, the average monthly temperatures and relative humidity of the air were calculated over the 240 days of storage. The temperature ranged from 20 to 26 ºC and the relative humidity from 41 to 72% (Figure 1).

Analysis performed

Every two months of storage in the different environments studied, packages with the referred seed treatments were removed and submitted to the analyzes below:

Water content - The water content in wet basis of the seeds was determined by the greenhouse method, with forced ventilation at 105 ± 3ºC for 24 hours, using two sub-samples for each repetition, according to the Rules for Analysis of Seeds - RAS (Ministério da Agricultura, Pecuária e Abastecimento [MAPA], 2009).

Germination - carried out with four samples of 50 seeds, in a Biomatic TIC-175 germinator, with temperature at 25 ± 2 ºC. The substrate used was germitest paper, moistened with distilled water in the proportion of 2.5 times the weight of the paper, in the form of rolls, which were packed in polyethylene bags, grouped by repetitions and kept in an upright position. Normal seedlings were counted on the fifth and eighth day after sowing and, in this last count, abnormal seedlings and dead and dormant seeds were also determined, according to RAS (MAPA, 2009).

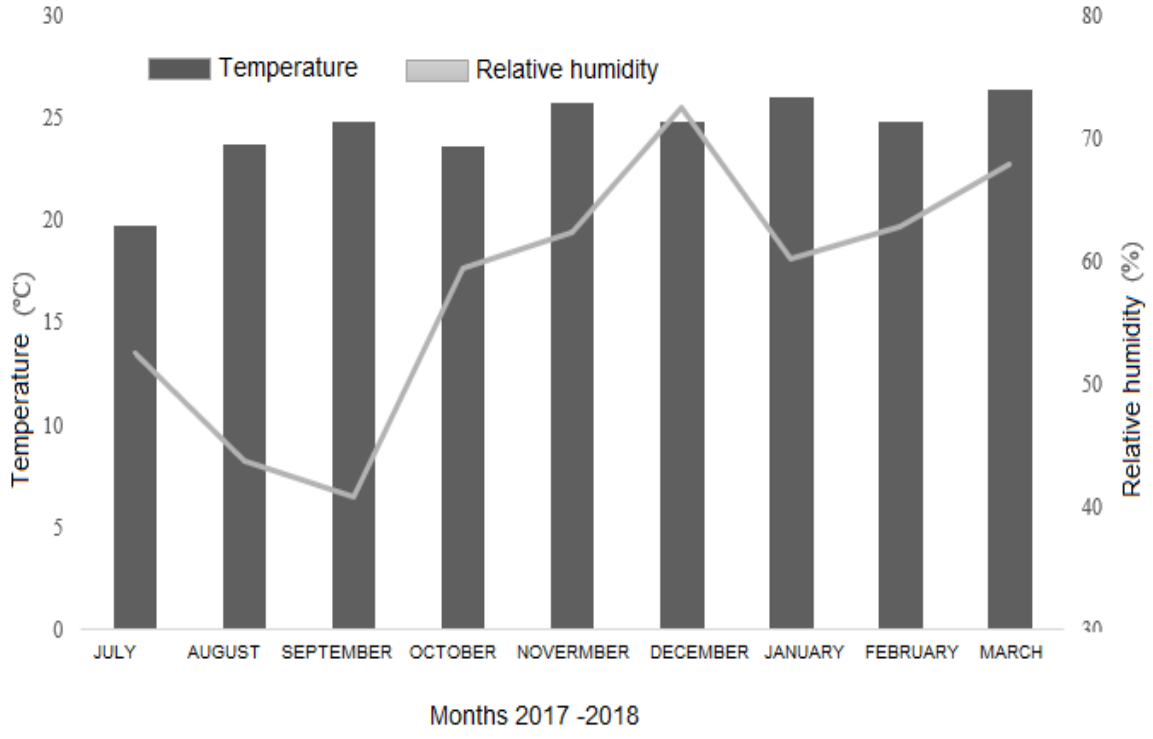


Figure 1. Average temperature (ºC) and relative humidity (%) in the laboratory environment, in Anápolis-GO, Brazil, during the storage time of soybean seeds, treated with fungicides and insecticides.

First count - The percentage of normal seedlings observed five days after the installation of the germination test was analyzed (MAPA, 2009).

Seedling length- The seedling length test was performed with a paper substrate, moistened as indicated for the germination test, using four repetitions of 10 seeds. Sowing was carried out on germitest paper on a line drawn in the upper third, in the transversal direction. The substrates in the form of rolls were placed in polyethylene bags, grouped by repetition of each treatment, kept vertically in a germinator regulated at 25 ± 2 ºC, for seven days. After this period, measurements were made, with the aid of a ruler graduated in mm, of the aerial part and main root of normal seedlings and the average length of each part was calculated, represented by the quotient between the sum of the seedling measurements in each repetition. The results were expressed in cm, with one decimal place (Vieira & Carvalho, 1994).

Seedling dry mass - Normal seedlings obtained in the length test had the reserve tissues removed with a scalpel and placed in kraft paper bags to dry in a greenhouse at 80 ± 2 ºC for 24 hours. After this period, the samples were evaluated with the aid of a digital scale (0.0001gr) to calculate the mass per seedling (m.g seedling^{-1}) (Vieira & Carvalho, 1994).

Statistical analysis

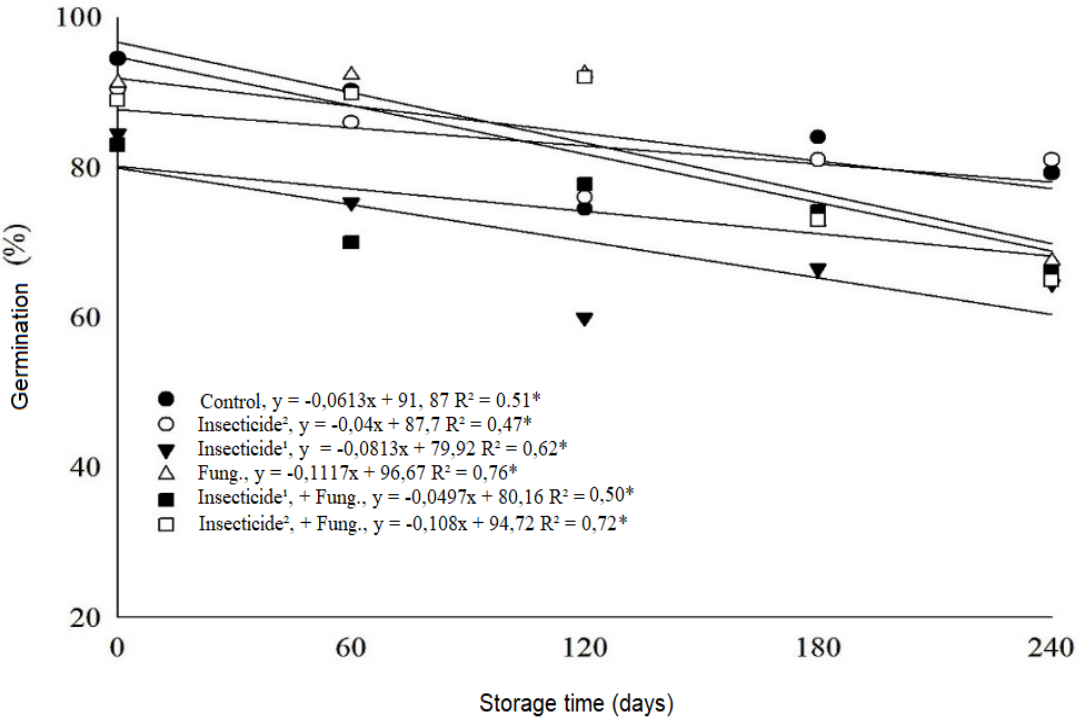
The data of the water content, present in the seeds during the storage time in both environments were submitted to descriptive analysis. The other tests evaluated were subjected to analysis of variance by the F test at 5% probability and, when significant, the means of the environmental factors and chemical treatments were compared by the Tukey test at 5% probability. Regression analyzes were performed for the storage time factor. The Sisvar software 5.6 was used to perform the statistical analyzes.

Results and Discussion

There was a significant interaction between environment x chemical treatment for the parameter's hypocotyl length, root length, dry root mass and emergence speed index. The interaction between environment x storage time, chemical treatment and storage time were significant in all parameters. There were also triple interactions for the first count of the germination test, length of hypocotyl, dry mass of hypocotyl and dry mass of root and emergence speed index.

Germination was influenced by the interaction between chemical treatments and storage time (Figure 2). Before storage, the highest percentages of normal seedlings were obtained in the control - 94%, followed by Metalaxil treatments; Tabendazole; Fludioxonil and Fipronil, all showing viability above 90%. The other treatments showed germination percentages higher than 80%, the minimum accepted value for seed commercialization (MAPA, 2009). In assessments that occurred at 60 days of storage, treatment with Metalaxil; Tabendazole; Fludioxonil stood out, maintaining the germination percentage above 90%, the control treatments, Fipronil and Fipronil + Metalaxil; Tabendazole; Fludioxil maintained germination percentages between 80% and 90%.

At 120 days of storage, the treatments Metalaxil-M, Tabendazole; Fludioxonil and Fipronil + Metalaxyl-M, Tabendazole; Fludioxonila showed viability percentages higher than 90%. After 180 days of storage, the control and seeds treated with Fipronil showed a germination percentage higher than 80% and at 240 days of storage, treatment with Fipronil showed germination of 81%, followed by the control, treatment without adding agrochemicals with 80%.



Env.1: Laboratory environment without temperature control and air relative humidity.
Env.2: Cold room environment with temperature control and air relative humidity.
Witness: Absence of chemicals; Insecticide¹: Fipronil; Insecticide²: Tiametoxam: Fung.:Mexalaxil-M; Tabendazol; Fluxodioxonil

Figure 2. Average germination percentage values of soybean seeds as a function of the interaction between treatments with fungicides, insecticides and the storage time for 240 days.

In evaluating the viability of the seeds by the standard germination test, it was observed for seeds without treatment and treated with Fipronil viability greater than 80% up to 60 days and treatments with Metalaxil; Tabendazole; Fludioxonil and Fipronil + Metalaxil; Tabendazole; Fludioxonil maintained germination above 80% until 120 days of storage. The treatments Tiametoxam and Tiametoxam + Metalaxil; Tabendazole; Fludioxonil after storage, provided a reduction in seed viability.

Treated and stored seeds may show a decrease in viability due to damage to membranes and the phytotoxic effect that the products may have on seeds. In the test estimates, the variations of normal seedlings of the treatments showed decreasing linear equations.

Analyzing the physiological quality of soybean seeds treated with insecticides and submitted to storage, L. G. M. Dan et al. (2010) found results in which the interaction between the factors had a negative effect on germination, decreasing linearly with the prolongation of the storage time. They also highlight that the treatments with the insecticides Fipronil, Tiametoxam, Imidacloprid, and Imidacloprid + Tiodicarb presented germination percentages above 80% in the period of 45 days of storage. Result that corroborates those obtained in this study for the treatment with the insecticide Fipronil that maintained the germination above 80% until 60 days after treatment and storage.

Some works carried out by Conceição et al. (2014) evaluating the physiological and sanitary quality and the performance of seedlings in the field of soybean seeds treated with fungicide Carbendazin + Thiram, insecticide, Imidacloprid + Tiodicarb, micronutrient, Grap 180 JE, and polymer, found that the germination did not show significant effect in response to product application. For Bays et al. (2007), the application of the fungicide Carbendazin + Thiram and micronutrient (CoMoB) and coating with polymer, also did not promote significant effect of the application on the germination of soybean seeds.

The interaction between the environment and the storage time for germination was significant (Figure 3). The laboratory and cold room environments presented adjustments to the regression curves with decreasing linear equations. The fact that the cold room has controlled conditions of relative humidity and temperature, justifies the generation of a more suitable environment for maintaining the viability of seeds during storage. Assessing the physiological quality of soybean seeds belonging to the cultivars BMX Apolo RR, BMX Poder RR and FUNDACEP 53 RR, in relation to the place and period of storage, F. C. Ferreira et al. (2017) concludes that storage of seeds in cold conditions has potential for maintaining quality more than 210 days, but may vary depending on the cultivar.

In view of the results obtained, it can be seen that storage in a cold room environment showed a higher percentage of viability than the laboratory environment during the storage time. The percentage difference between the environments, may have occurred mainly due to the difference in relative humidity of the air between the environments under study. According to M. Silva et al. (2014), the process of deterioration of stored seeds is inevitable, however, exposed to fluctuations in humidity and varied temperature, as in uncontrolled places (laboratory), these lose viability, becoming susceptible to stress during germination and, thus, decrease the ability to produce normal seedlings, thus justifying the results obtained in the research.

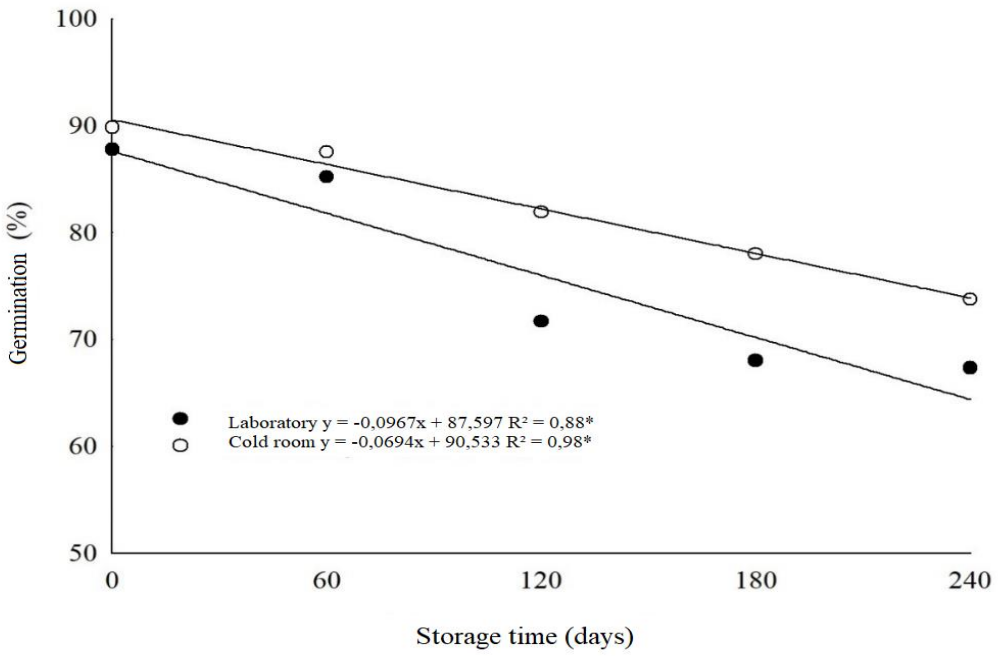


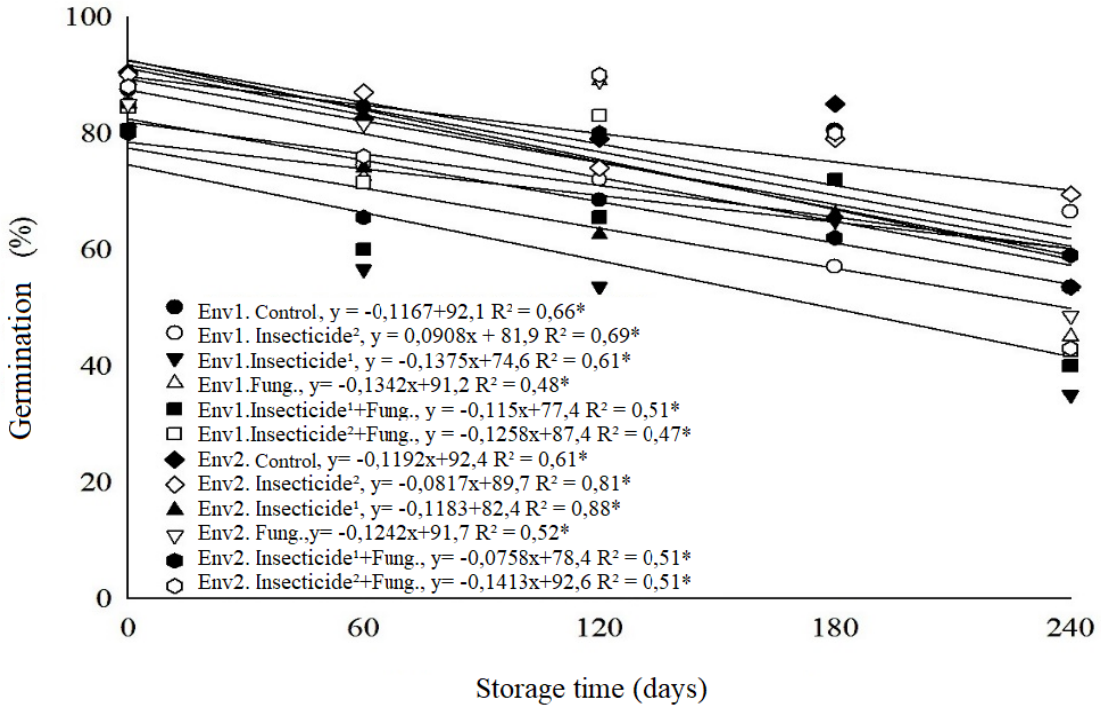
Figure 3. Average germination percentage values of soybean seeds, depending on different storage environments for 240 days.

In the first count of the germination test, the seed vigor was influenced by the interaction between environments, chemical treatment and storage time (Figure 4). All treatments showed vigor above 80% that was evaluated right after the application of treatments on the seeds without storage. When analyzed at 60 days after storage, seeds stored in a cold room and treated with the insecticide Fipronil showed greater vigor followed by the control in the laboratory and cold room environments and the fungicide Metalaxil-M; Tabendazole; Fludioxonil that presented percentage above 80% of seedling vigor, superior to the other treatments.

After 120 days of storage in both environments, the Metalaxil-M treatments; Tabendazole; Fludioxonil and Fipronil + Metalaxyl-M; Tabendazole; Fludioxonil showed vigor greater than 80%, with emphasis on the cold room environment where the treatments Tiametoxam + Metalaxil-M; Tabendazole; Fludioxonil, Control and Fipronil, with values close to 80%. At 180 days, control treatments stand out, the fungicide Metalaxil-M; Tabendazole; Fludioxonil and the insecticide Fipronil associated with the fungicide Metalaxil-M; Tabendazole; Fludioxonilonde in both storage situations showed 80% in vigor. At 240 days of storage, all treatments showed germination percentage below 70%.

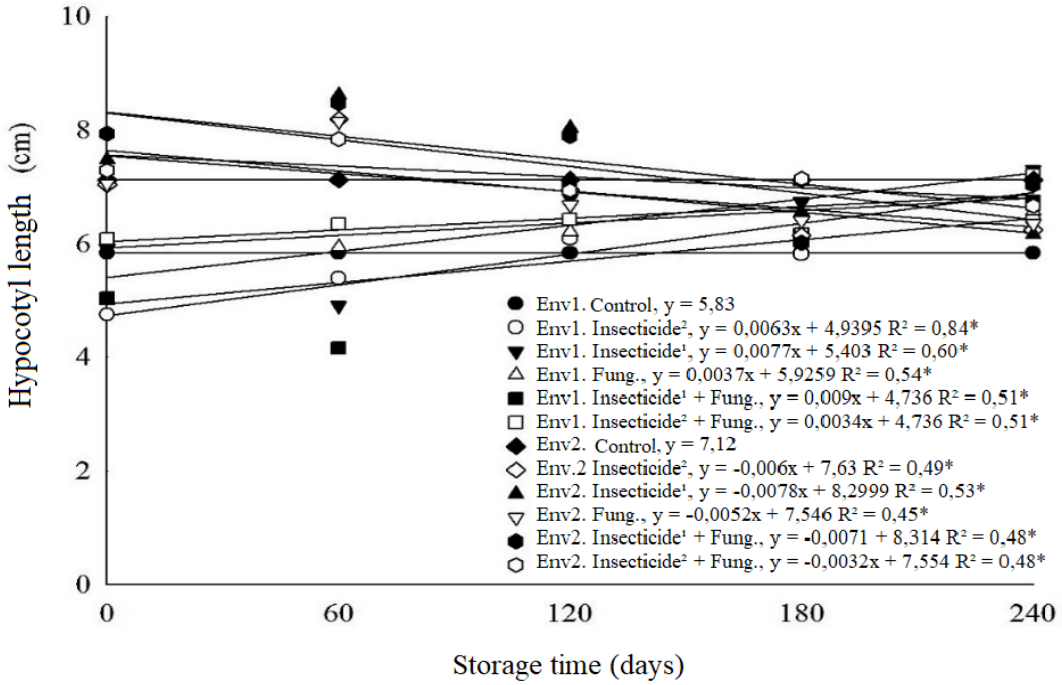
The results of the first count test show that the treatments showed behavior described by decreasing linear regression equations in the two storage environments. It was also found that the reductions in normal seedlings were more pronounced in the seeds kept in the laboratory environment, in agreement with the results of research by Smaniotto et al. (2014) and F. C. Ferreira et al. (2017).

As in the first count test, the seedling length test by measuring the length of the hypocotyl was influenced by the interaction between environmental factors, chemical treatments and storage time (Figure 5). In the analyzes performed, all treatments showed seedlings with a hypocotyl length greater than 4 centimeters.



Env1: Laboratory environment without temperature control and air relative humidity
Env2: Cold room environment with temperature control and air relative humidity
Witness: Absence of chemicals; Insecticide¹ : Fipronil; Insecticide²: Tiametoxam;
Fung.:Metalaxil-M; Tabendazol; Fludioxonil.

Figure 4. Average germination percentage values obtained from the first count test of soybean seeds treated with fungicides and insecticides and stored in laboratory and cold room environments.



Env1: Laboratory environment without temperature control and air relative humidity.
Env2: Cold room environment with temperature control and air relative humidity.
Witness: Absence of chemicals; Insecticide¹: Fipronil; Insecticide²: Tiametoxam;
Fung.: Metalaxil-M; Tabendazol; Fludioxonil.

Figure 5. Average hypocotyl length values of soybean seedlings, treated with fungicides and insecticides and stored in laboratory environments (A) and cold room (B).

In the storage environments, the treatment data were adjusted to linear regression models, except for the control treatment that did not present a regression curve adjustment, with only the means of the hypocotyl length being presented for both environments.

Treatment with the combination of Fipronil + Metalaxil-M; Tabendazole; Fludioxonil showed the highest average length of hypocotyl during all storage times. When stored in a cold room, treatment with Tiametoxam + Metalaxil-M; Tabendazole; Fludioxonil, Tiametoxam and Fipronil + Metalaxil-M; Tabendazole; Fludioxonil had the best averages of hypocotyl length in all packaging periods, followed by treatment with Fipronil which also had the best means until 60 days.

According to Nakagawa (1999), evaluating the length of the hypocotyl has the objective of estimating the relative vigor of the seed mass. This observation is valid, becauseas vigorous seeds lead to seedlings with high growth rates and transformation capacity, resulting from the greater supply of storage tissue reserves and a high inclusion of these by the embryonic axis (E. Dan et al., 1987).

Thus, it can be inferred that treatment with Fipronil + Metalaxil-M; Tabendazole; Fludioxonile Fipronil in a laboratory environment provided an increase in the growth of the hypocotyl up to 120 days of storage. On the other hand, the treatment with the insecticide Tiametoxam and the associated fungicide + insecticide in a cold room environment did not harm the development of the hypocotyl, because the averages obtained were superior to the treatment without the addition of agrochemicals (control), besides to present the best results averages for the length of the hypocotyl among other treatments tested throughout the storage time.

This result is similar to those obtained in the study by Conceição et al. (2014) when evaluating the physiological quality of soybean seeds treated with Carbendazin + Thiram fungicides, insecticide, Imidacloprid + Tiodicarb, micronutrient Grap 180 JE verified that the treatments presented results similar to the control, in other words, it had no positive or negative effect on the length of the hypocotyl. The author also remembers that the information obtained in the test must be interpreted taking into account the germination percentage, besides the seedling length or part of it.

When analyzing the effect of different treatments on the physiological quality of soybean seeds, L. C. Pereira et al.(2016), verified that the treatments Carbendazim + Chlorantraniliprole + polymer + micronutrients + drying powder + bioregulator, Metalaxil-M; Tabendazole; Fludioxonil + Thiametoxam + polymer + drying powder + nematicide / insecticide + micronutrients + bioregulator were statistically equal to the test for the shoot length test, thus corroborating the results of this research.

It was also possible to verify that the storage environments interfered with the development of the radicle length (Table 2).

Table 2
Average root length (cm) values of soybean seedlings treated with fungicides and insecticides and stored in different environments

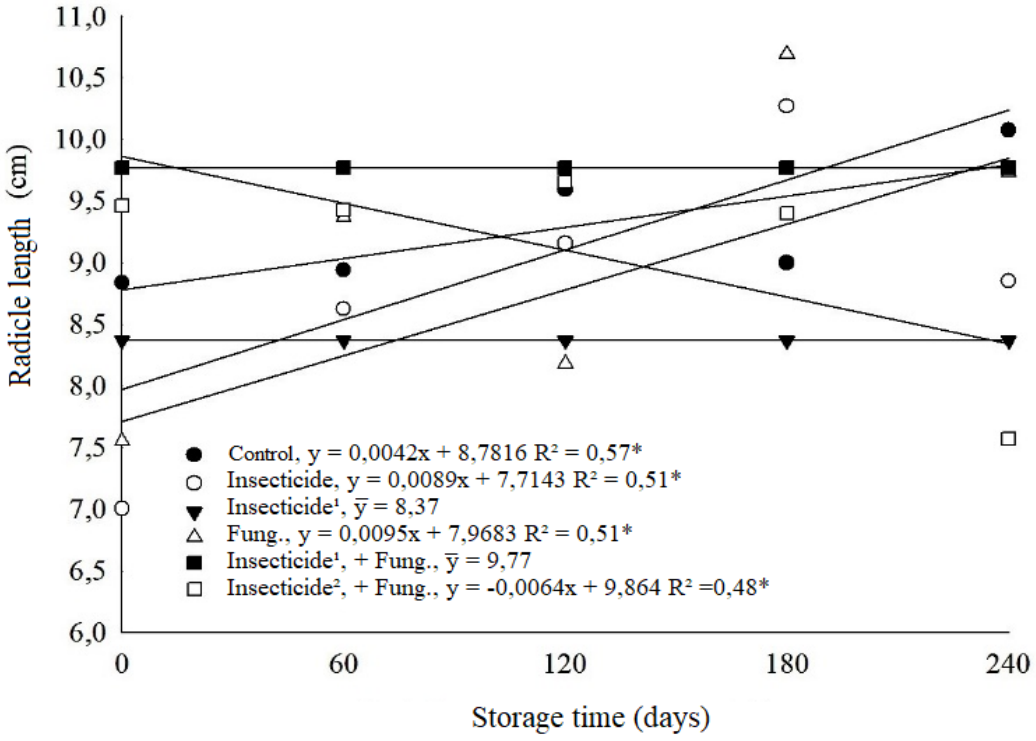
Environment	Chemical Treatment					
	Control	Insect[2]	Insect[1]	Fung.	Fung.+Insect[1]	Fung.+Insect[2]
Laboratory	7,6abB	6,9bB	7,5abB	8,3aB	8,1abB	8,5Ab
Cold room	10,7abA	10,6abcA	9,2dA	9,3cdA	11,5aA	9,6bcdA

Averages followed by the same letter, small letter on the line, capital letter on the column, do not differentiate by Tukey's test at 5% probability. Control: Absence of chemicals; Insect[2]: Fipronil; Insect[1]: Tiamentoxan; Fung.: Metalaxyl-M; Tabendazole; Fludioxonil.

The cold room provided better root performance for the treatment Tiametoxam + Metalaxil-M; Tabendazole; Fludioxonil, which did not differ from the Control eFipronil treatments and was superior to the Tiametoxam, Metalaxil-M treatments; Tabendazole; Fludioxonil and Fipronil + Metalaxyl-M; Tabendazole; Fludioxonil.

The laboratory environment negatively influenced the development of seedling root when the seeds were subjected to the treatments Control, Fipronil, Tiametoxam, Metalaxil-M; Tabendazole; Fludioxonil, Tiametoxam + Metalaxyl-M; Tabendazole; Fludioxonil and Fipronil + Metalaxyl-M; Tabendazole; Fludioxonil, compared to the cold room environment. In the laboratory environment treatments with Metalaxil-M; Tabendazole; Fludioxonil and Fipronil + Metalaxyl-M; Tabendazole; Fludioxonil stood out as superior in relation to the Fipronil treatment, not differing from the Control, Tiametoxam and Tiametoxam + Metalaxil-M treatments; Tabendazole; Fludioxonil.

About the interaction between chemical treatments and storage time (Figure 6), it can be seen that the treatments showed linear behavior, except for the treatments with the insecticide Tiamentoxam and Tiametoxam associated with the fungicide Metalaxil-M; Tabendazole; Fludioxonil that did not show adjustment of regression curves due to the variability of the data, being presented the averages of 8.3 and 9.7 cm, respectively.



Witness: Absence of chemicals; Insecticide²: Fipronil; Insecticide¹: Tiametoxam; Fung.: Metalaxil-M; Tabendazol; Fludioxonil.

Figure 6. Average root length values of soybean seedlings treated with fungicides and insecticides.

The treatment with the absence of insecticides and fungicide stands out, which showed an increase in root growth over the storage period. The other treatments with Fipronil and Metalaxil-M; Tabendazole; Fludioxonil show a tendency for root growth over the storage time. Unlike treatment with the insecticide Fipronil associated with the fungicide Metalaxil-M; Tabendazole; Fludioxonil that owes a reduction in the radicle length during the storage time.

The control treatment provided higher mean radicle length during the 240 days of storage followed by treatments associated with Fipronil + Metalaxil-M; Tabendazole; FludioxonileMetalaxil-M; Tabendazole; Fludioxonil. It is observed that the treatments with the insecticides Fipronil and Tiametoxam had smaller roots than the treatment without the addition of chemicals.

The results obtained regarding the radicle length as a function of the treatments applied to soybean seeds during storage corroborate the study carried out by L. G. M. Dan et al. (2010), who evaluated the physiological quality of soybean seeds treated with the insecticides Tiametoxam, Fipronil, Imidacloprid, Imidacloprid + Tiodicarp, Carbofuran and Acephate and submitted to four storage times (0, 15, 30 and 45 days), found that all the insecticides used in seed treatment negatively influenced the root development of soybean seedlings.

Matching results are also presented in the study by Brzezinski et al. (2017), who evaluated the effect of seed storage treated with different associations of fungicides, insecticides and nematicides on the development of soybean seedlings, found that the treatment of seeds with the active ingredients Imidacloprid + Thiodicarb + Carbendazin + Thiram provided a decrease in root length.

The radicle length values from seeds stored in the laboratory environment showed high variability, where the radicle length averages showed a growth trend over the storage time. In a cold room environment, the root development of soybean seedlings with greater mean root length compared to the laboratory environment. However, with equation adjustment with a quadratic model, providing an increase in primary root growth until 120 days of storage.

The storage phase is of utmost importance, as it must maintain the viability and vigor of the seeds for a longer time, maintaining their physiological quality. However, variations in environments contribute to the longevity or not of seed quality. Therefore, this is a critical phase for maintaining seed vigor, usually with significant interaction between environments and storage time, as found in this research (Figure 7).

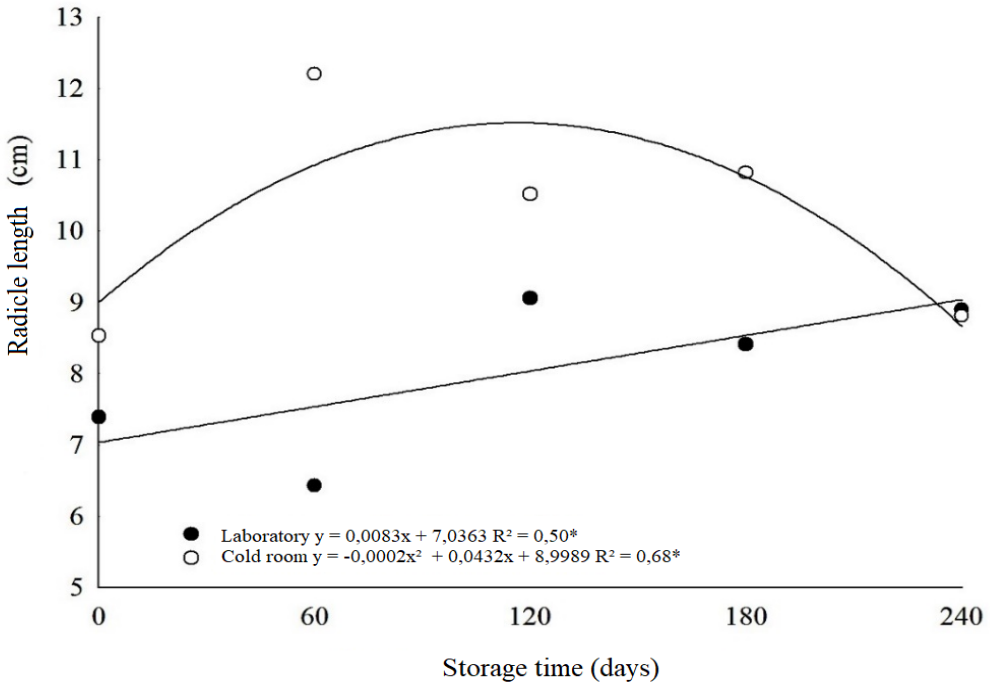
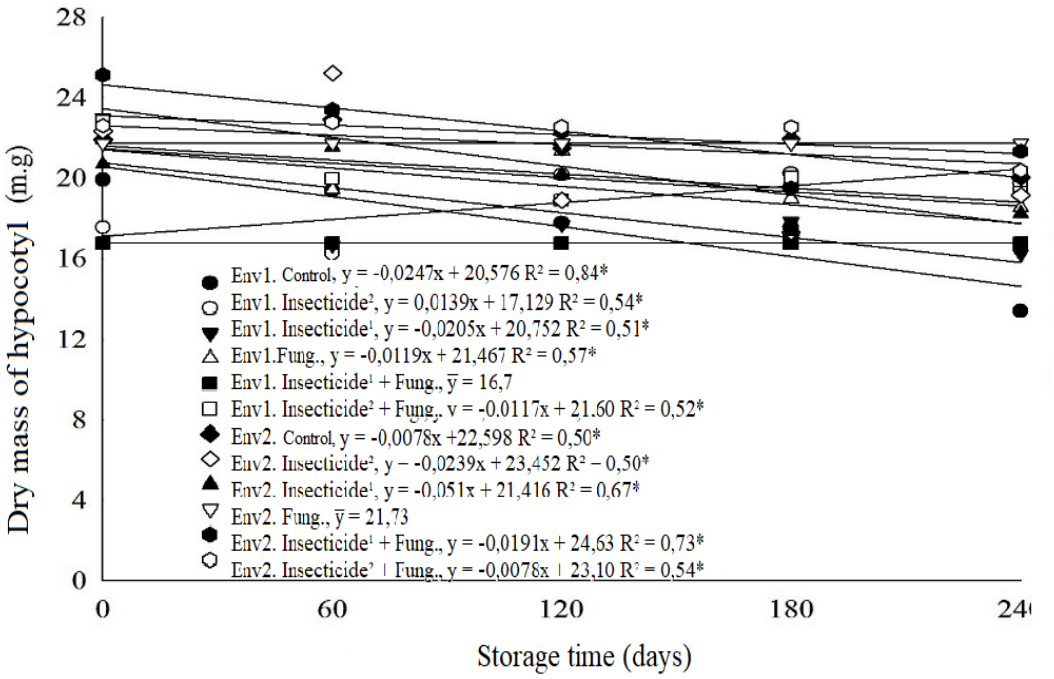


Figure 7. Average seed radicle length values as a function of different storage environments for two hundred and forty days. Anápolis-GO, UEG, 2018.

In a study by Juvino et al. (2014) concluded that the vigor, germination and emergence of soybeans remain elevated in a period of nine months of storage, and the root length and number of normal young seedlings were negatively influenced by time, mainly in a natural environment in relation to the acclimatized environment, unlike the results found where in an environment without temperature and relative humidity control, the radicle length showed a growth trend over the storage time.

In the hypocotyl dry mass test (Figure 8), the Control treatment, Tiametoxam and Fipronil + Metalaxil-M; Tabendazole; Fludioxonil showed a reduction in dry weight over the storage time, with adjustments to decreasing linear regression equations in both storage environments. Seed treatments with Metalaxil-M; Tabendazole; FludioxonileTiametoxam + Metalaxil-M; Tabendazole; Fludioxonil showed adjustments to decreasing linear regression equations only in the laboratory and cold rooms, respectively. As they did not present adjustments in the regression curves, averages were presented for the Metalaxil-M treatment; Tabendazole; Fludioxonil in cold room environment and Tiametoxam + Metalaxil-M; Tabendazole; Fludioxonil in a laboratory environment.



Env1: Laboratory environment without temperature control and air relative humidity.
Env2: Cold room environment with temperature control and air relative humidity.
Witness: Absence of chemicals; Insecticide¹ : Fipronil; Insecticide²: Tiametoxam; Fung.:Metalaxil-M; Tabendazol; Fludioxonil.

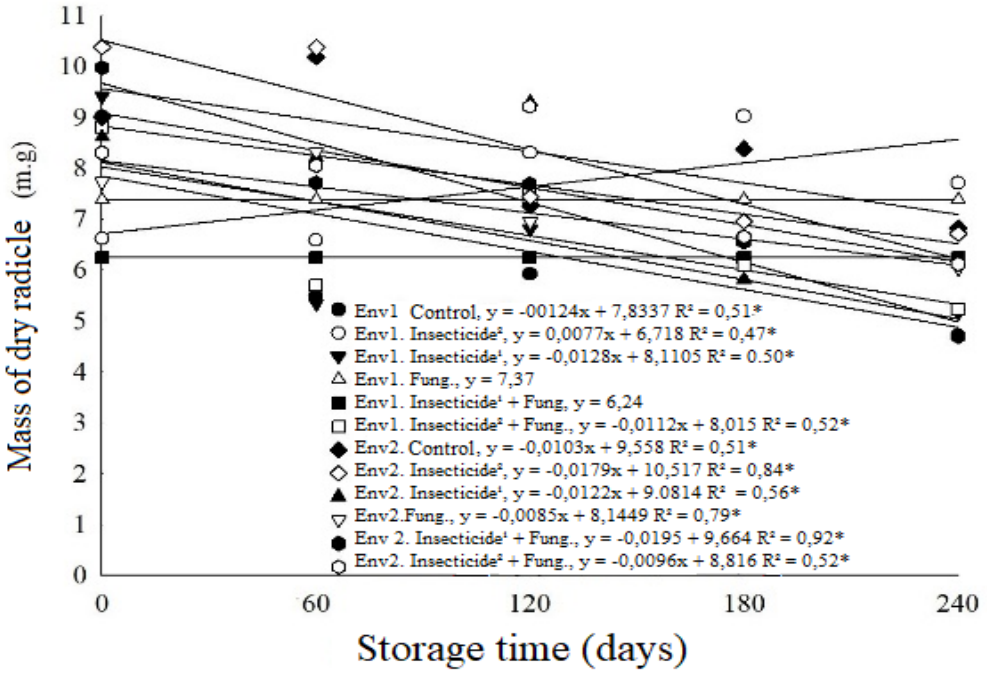
Figure 8. Average dry mass of hypocotyls values of soybean seedlings treated with fungicides and insecticides and stored in laboratory and cold room environments.

Observing the results of seedling length (Figure 5), and comparing with the results verified for the test in question, it can be seen that the treatments that presented greater seedling length also presented greater weight of dry mass. In this way, it can be inferred that the seeds treated with Tiametoxam + Metalaxil-M; Tabendazole; Fludioxonil and Fipronil + Metalaxyl-M; Tabendazole; Fludioxonil and stored for 240 days in a laboratory environment, showed the capacity to transform the tissue reserve supplies, and their high incorporation through the embryonic axis.

In works developed by Dan et al. (2012) and Ludwig et al. (2015), using different agrochemicals such as Fludioxonil + Metalaxil-M, Tiametoxan and Deltamethrin in the treatment of soybean seeds, did not detect any effects that contributed to the increase or decrease in dry root mass. Unlike the results of this research, in which the use of the insecticide with active ingredient Tiametoxam associated with Metalaxil-M; Tabendazole; Fludioxonil and Fipronil + Metalaxyl-M; Tabendazole; Fludioxonil provided the best seedling performances, both in mass and in length of hypocotyl.

Analyzing the interaction of environmental factors with chemical treatments in the storage times studied for the dry root mass test, it is noted that the treatments

practically showed similar behaviors in the investigated environments (Figure 9). The Control treatments, Tiametoxam, Fipronil + Metalaxil-M; Tabendazole; Fludioxonil, in both environments, Fipronil, Metalaxil-M; Tabendazole; Fludioxonil and Tiametoxam + Metalaxyl-M; Tabendazole; Fludioxonil in a cold room showed decreasing linear regression equations, showing a decrease in the weight of the dry root mass during storage.



Env1. Laboratory environment without temperature control and air relative humidity.
Env2. Cold room environment with temperature control and air relative humidity.
Witness: Absence of chemicals; Insecticide²: Fipronil; Insecticide¹: Tiametoxam; Fung., Metalaxil-M; Tabendazol; Fludioxonil.

Figure 9. Average mass of dry radicle values from soybean seedlings, treated with fungicides and insecticides and stored in laboratory and cold room environments.

The treatment with the insecticide Fipronil in the laboratory environment had a different behavior when presenting with a tendency to increase in mass during the storage time. Treatments with Metalaxil-M; Tabendazole; Fludioxonil and Tiametoxam + Metalaxyl-M; Tabendazole; Fludioxonil in a laboratory environment did not present adjustments in the regression curve, obtaining average values of dry root mass corresponding to 7.4 and 6.2 mg, respectively.

The behavior of this test was different to that verified in a study by Brzezinski et al. (2017), when he observed that the use of some fungicide-based products, provide plants with greater roots and mass, and

that their averages have decreased during storage. Cunha et al. (2015), consider the importance of increasing the dry root mass, since this is linked to the greater development of secondary, thinner roots, thus favoring the absorption of nutrients from the soil.

Thus, it can be inferred that the increase in humidity in the laboratory environment, during the storage time, caused the IVE to be lower than the cold room environment. In this way, the results obtained in this research, the chemical treatments did not cause damage to the seed emergence speed when stored in a cold room environment.

Conclusions

Chemical treatments negatively affect the germination potential of seeds, especially after 120 days of storage, regardless of the environment. Thiamethoxam and Thiamethoxam + Metalaxil; Tabendazole; Fludioxonil after storage provided the biggest reductions in seed viability and vigor after 240 days of storage. Cold room environment provides better conditions for the conservation of the germinative potential of soybean seeds compared to the laboratory environment.

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