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ARTICLE

Chemical treatment and storage of sorghum seeds produced in different management zones

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ABSTRACT: Precision Agriculture considers soil attributes and production aspects to define management zones. Although there is little information, it is likely that seeds produced in different management zones have different quality after chemical treatment and storage. The aim was to evaluate the physiological quality of sorghum seeds produced in different management zones, after chemical treatment and storage. The management zones were defined from interpolated maps of soil and vegetation attributes with the aid of the Smart Map - SMP plugin, in a Qgis environment. After harvest, the seeds were treated with Thiamethoxam, Imidacloprid + Thiodicarb, Fludioxonil + Metalaxyl-M and a control treatment (water). Then, they were stored for 0, 60 and 120 days. The seeds were evaluated for their quality through the following tests: moisture, germination, dry mass of seedlings, electrical conductivity, and accelerated aging. The design was completely randomized in a 4 × 3 factorial scheme, with the management zones being analyzed independently. Sorghum seed treatments with insecticides cause greater phytotoxicity during storage in both management zones, unlike the fungicide treatment. Sorghum seeds produced in high-management zones have high physiological quality and less deterioration during storage. Sorghum seeds produced in low-management zones treated with insecticides, as the storage time increases, show lower vigor due to deterioration and phytotoxicity.

Index terms: precision agriculture, seed treatment, *Sorghum bicolor* L., toxicity.

RESUMO: A Agricultura de Precisão considera atributos de solo e aspectos produtivos para elaboração de zonas de manejo. Apesar de poucas informações, é provável que sementes produzidas em diferentes zonas de manejo tenham qualidade distinta após o tratamento químico e armazenamento. Objetivou-se avaliar a qualidade fisiológica de sementes de sorgo produzidas em diferentes zonas de manejo, após o tratamento químico e o armazenamento de sementes. As zonas de manejo foram definidas a partir de mapas interpolados de atributos de solo e vegetação com auxílio do plugin Smart Map - SMP, em ambiente Qgis. Após a colheita, as sementes foram tratadas com Thiametoxam, Imidacloprid + Thiodicarb, Fludioxonil + Metalaxil-M e um tratamento controle (água). Em seguida foram armazenadas por 0, 60 e 120 dias. As sementes foram avaliadas quanto a sua qualidade por meio dos testes: de umidade, germinação, massa seca de plântulas, condutividade elétrica e envelhecimento acelerado. O delineamento foi inteiramente casualizado em esquema fatorial 4 × 3, sendo as zonas de manejo analisadas de forma independente. Os tratamentos de sementes de sorgo com inseticidas causam maior fitotoxidez no armazenamento em ambas as zonas de manejo ao contrário do tratamento fungicida. Sementes de sorgo produzidas em zonas de alto manejo possuem alta qualidade fisiológica e com menor deterioração no armazenamento. Sementes de sorgo produzidas em zonas de baixo manejo tratadas com inseticidas mediante aumento dos períodos de armazenamento apresentam menor vigor devido a deterioração e fitotoxidez das sementes.

Termos para indexação: agricultura de precisão, tratamento de sementes, *Sorghum bicolor* L., toxicidade.

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INTRODUCTION

Sorghum bicolor L., a cultivated cereal that adapts to tropical climates (Pramono et al., 2018) being the fifth most cultivated in the world (Pontieri et al., 2020). The crop has great relevance in the current scenario and can be used in human and animal diet, in addition to ethanol production. The Brazilian production of sorghum is significant, 3.0 million tons in an area of 950,200 hectares, with an average yield of 3,200 kg.ha^{-1} in the 2021/22 crop season. In this scenario, the state of Goiás stands out as the main producer (CONAB, 2022).

According to Lopes et al. (2001), the increase in production and expansion of the planted area are obtained according to the technology used, especially the use of high-quality seeds, indispensable for the production success of any crop. Thus, low-quality seeds can change the emergence speed, with influence on the uniformity of the plantation and establishment of the appropriate stand (Marcos-Filho, 2015). In this context, some techniques have become of great utility in seed production.

Precision Agriculture is a technique to collect information on soil chemical and physical attributes, crop conditions, topography, and yield, associating them with their location, which in turn can be expressed in the form of maps that demonstrate the spatial and temporal distribution of the observed attributes (Corrêa et al., 2021). Precision Agriculture does not consider the plantation, but by management zones or referenced management units, which are subareas with the same yield response tendency (Milani et al., 2006). The management zones are defined according to the yield potential (low, medium, or high), hence not being treated with homogeneity, allowing the localized application of inputs and variable-rate seeding (Milani et al., 2006).

Seed treatment is another tool used to increase yield. It consists in the application of chemical pesticides such as insecticides and fungicides, or biological products that are used to provide the plant with conditions to defend itself against the attack of pests and pathogens. This allows greater potential for the initial development of the crop, in addition to maintaining the planned plant stand. In Brazil, the percentage of seeds treated with chemicals is constantly increasing, and this is already a consolidated practice for several crops (Carvalho et al., 2020).

Although the use of chemical pesticides in seed treatment is considered one of the most efficient methods for the application of phytosanitary products, research results have shown that some products, such as fungicides and insecticides, applied to seeds may cause reductions in germination and seedling survival, due to phytotoxic effects, in certain situations (Carvalho et al., 2020).

One of the situations that can cause loss of seed quality is when the seeds are treated and then stored. Brzezinski et al. (2015), Ferreira et al. (2016) and Santos et al. (2018) mention problems in soybean seeds stored for long periods, when already treated with chemical ingredients, with possibility of phytotoxic effects that can compromise physiological quality.

Depending on how long in advance the seeds are treated, treatment before packing can be harmful. In this process, technical and logistical issues determine that seeds must be treated before being packed and stored until the time of sowing (Brzezinski et al., 2015). Therefore, monitoring the time that the seed can remain with the treatment with no damage to its physiological quality is of great importance.

Thus, the aim of this study was to evaluate the physiological quality of sorghum seeds produced in different management zones after chemical treatment and storage.

MATERIAL AND METHODS

Seeds of the sorghum hybrid 50A60 were produced in a center pivot area at *Capim Branco* Farm (18°53’24.5” S; 48°20’27.1” W), belonging to the *Universidade Federal de Uberlândia* (UFU). The region has a climate of type Aw (Köppen-Geiger), tropical with dry season in winter, and average precipitation of 1,479 mm. The study area, of 25 ha, has an average altitude of 825 m, and the soil is classified as *Latossolo Vermelho Escuro distrófico* (Oxisol), cultivated with grain crops in no-tillage system since 2012, with soybean crop in first season, followed by maize or sorghum, in succession.

Previously, a regular, systematically randomized grid with 50 sampling points was delimited. The recognition of the points in the field and the collection of elevation data were carried out with the aid of the global navigation satellite system - GNSS, using the Garmin e-Trex Vista® navigation GPS, equipped with barometric altimeter. The management zones were defined with the aid of the Smart Map - SMP plugin, in Qgis Environment (Qgis Development Team, 2015) (Figure 1A). The attributes analyzed for defining the zones were altitude, sand, clay, electrical conductivity, soil penetration resistance and vegetation index (NDVI). During the experiment, the weather conditions were monitored (Figure 1B).

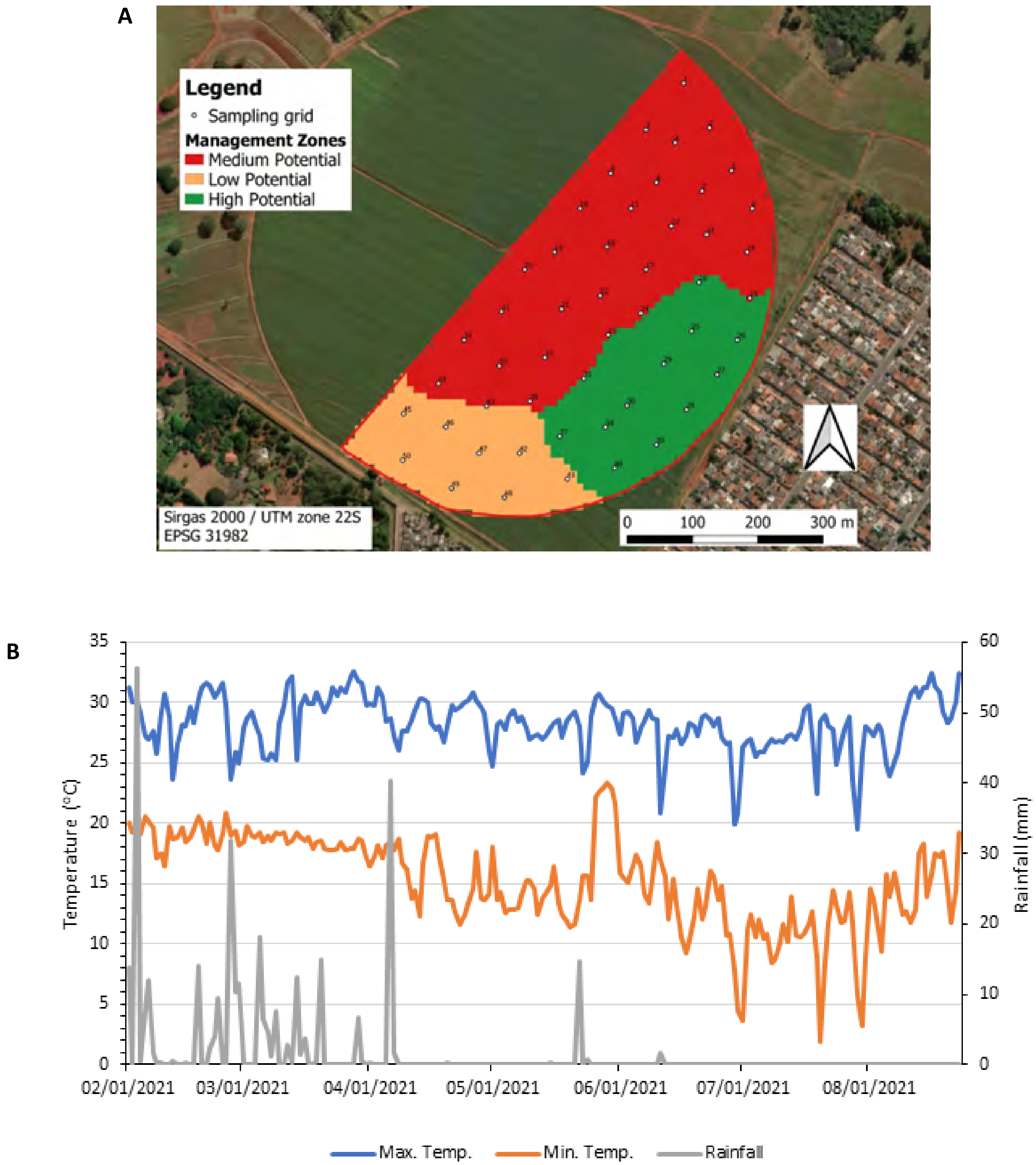


Figure 1. (A) Experimental area and definition of management zones for data collection. (B) Meteorological data: Rainfall (mm), maximum and minimum air temperature (°C) in the period of production and harvesting of sorghum seeds in the municipality of Uberlândia, MG.

The seeds were produced in zones of low and high yield potential, and harvest was carried out 146 days after sowing. In each of the yield zones, seeds were collected in four plots, containing four rows (0.5 m x 4 linear m), totaling 8 m^2 of harvested area. After harvest, the seeds were taken to the Seed Laboratory (LASEM) of the Institute of Agrarian Sciences of the *Universidade Federal de Uberlândia* (UFU), Minas Gerais, Brazil.

Initially, the seeds were processed and then homogenized in a soil homogenizer with 18 channels. The seeds underwent a chemical treatment, performed manually using plastic bags, which were shaken until they were completely covered by the solution. The volume of the solution was standardized as 600 mL.100 kg^{-1} of seeds. The dose used to prepare the solution followed the guidelines contained in the package leaflet of each product, plus distilled water in the equivalent quantity to complement the specified volume (Table 1).

After treatment, the seeds remained in a laboratory environment (25 °C/40% RH) for 48 hours for drying and adhesion of the products. Next, the seeds were placed in a multifoliate paper package and stored in a cold and dry chamber under conditions of temperature of 15 °C and relative humidity (RH) of 55%. Physiological quality evaluations were performed at 0, 60 and 120 days of storage. The seeds were then subjected to the tests described below:

Moisture content: evaluated at each storage time by the oven method at 105 °C ± 3 °C for 24 hours, using 2 seed replications with 4 to 5 grams, according to the guidelines contained in the Rules for Seed Testing (Brasil, 2009).

Germination: the seeds were evenly distributed between two sheets of paper for germination, with distilled water volume adjusted for soaking in the amount equivalent to 2.5 times the weight of the dry paper. Then, rolls of paper containing the seeds were made and placed in germinator at a temperature of 25 °C, under photoperiod of 12 hours. Four replications of 50 seeds were used for each treatment, and the evaluations were carried out at four and 10 days (Brasil, 2009). Normal, abnormal, and infected seedlings (resulting from fungal infection) were evaluated. The results were expressed as a percentage (%).

Accelerated aging: determined by the traditional method, based on the aging of seeds in Gerbox-type plastic boxes containing metal screen. Each Gerbox contained 40 mL of distilled water, and the seeds were deposited on a metal screen forming a single layer. Subsequently, the closed boxes were kept in BOD-type chamber at 43 °C for 72 hours (Marcos-Filho, 2020). Then, four replications of 50 seeds were subjected to the germination test according to the methodology described in Brasil (2009). The evaluation was performed four days after sowing, in normal seedlings, and the results were expressed in percentage (%).

Electrical conductivity: seed vigor was evaluated indirectly by determining the amount of leachates in the soaking solution. Four replications of 50 seeds were placed in disposable plastic cups (capacity of 200 mL), and the samples were previously weighed on a precision scale (0.001 g). Subsequently, 25 mL of deionized water was added to the cups containing the seeds and they were placed in a germination chamber previously regulated at 30 °C, where they were kept for 16 hours (Marques and Dutra, 2018). After the soaking period, the containers were removed from the chamber and the solution containing the seeds was stirred to standardize the leachates Reading was immediately performed in an MCA 150 conductivity meter, with constant 1 electrode, whose data were expressed in $\mu S.cm^{-1}.g^{-1}$ of seed.

Table 1. Active ingredients, commercial products, classification and application rates for treatment of sorghum seeds.

Active ingredient (a.i.)	Commercial name	Classification¹	Dose of commercial product²	Dose of water³
Thiamethoxam	Cruiser 350 FS	I	300	300
Fludioxonil + Metalaxyl-M	Maxim XL	F + F	100	500
Imidacloprid + Thiodicarb	Cropstar	I + I	500	100
Control	-	-	-	600

Classification¹: I: Insecticide; F: Fungicide; Dose of commercial product²: mL.100 kg^{-1} of seeds; Dose of water³: mL.100 kg^{-1} of seeds; Total volume: 600 mL.100 kg^{-1} of seeds.

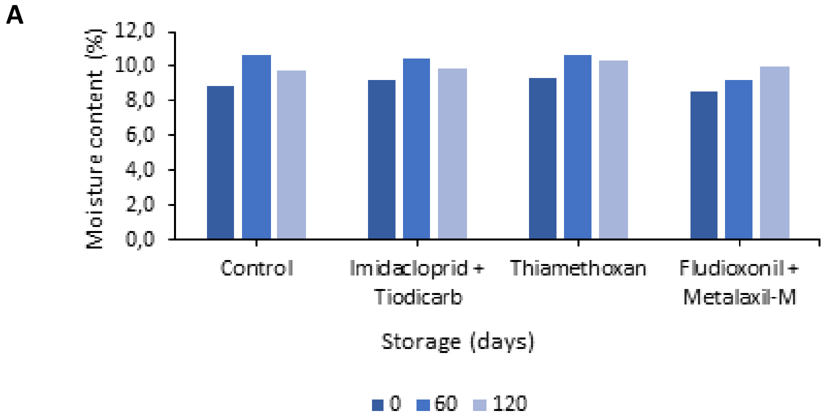
Dry mass: determined at 10 days in normal seedlings from the germination test. The normal seedlings were dried at 65 °C for 72 hours in a forced air circulation oven and, after this period, the material was weighed on a 0.001 g precision scale. The results were expressed in $g.seedling^{-1}$.

Statistical analysis and experimental design: the experimental design was completely randomized in a 4 × 3 factorial scheme (seed treatment × storage times), and the management zones were independently analyzed. For the statistical analysis of the data, the F test and the analysis of variance at 5% probability level were used; in case of significant effects, the means were compared by the Scott-Knott test at 5% significance level, using SISVAR 5.0 software (Ferreira, 2011).

RESULTS AND DISCUSSION

The physiological quality of sorghum seeds in the two management zones was influenced by chemical treatments and storage times. The moisture contents of sorghum seeds in the high- and low-management zones can be observed in Figures 2A and 2B, respectively.

In general, it is possible to observe that prior to storage the seeds had moisture content around 8%, regardless of the management zone and the chemical treatment performed (Figures 2A and 2B). The difference between the lowest and highest percentage was only 1%, ensuring reliability in the results of the evaluations of the physiological potential of the seeds. Marcos-Filho (2015) emphasized that samples with differences between 1 and 2% of moisture content do not compromise the results and the tests can be conducted.



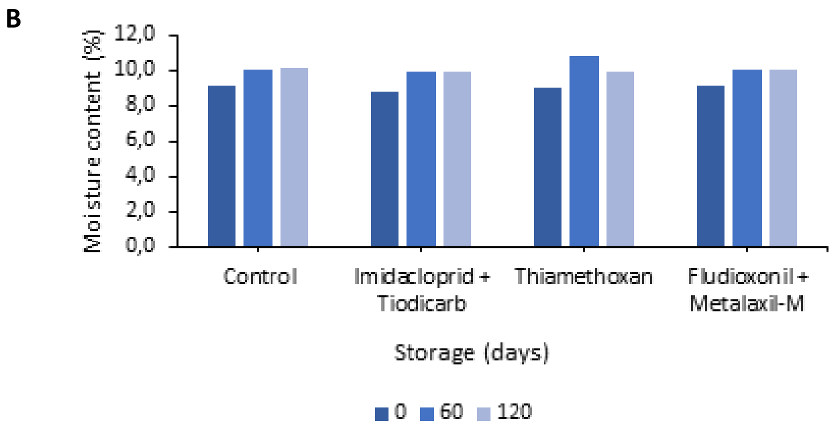


Figure 2. Moisture content of sorghum seeds produced in high- (A) and low- (B) management zones as a function of seed treatment and storage time.

After storage, sorghum seeds from high- and low-management zones had moisture contents ranging between 9% and 10%, being on average about 1% to 2% above the moisture content prior to storage. This increase is probably due to the relative humidity of the air at the times of 60 and 120 days of storage, which consequently increased the moisture contents of the seeds to restore the hygroscopic balance. However, it is worth mentioning that the seeds produced in the low-management zone (Figure 1B), treated with Thiamethoxam at 60 days of storage, showed moisture content of 10.9%, which was higher than the values found in the other seed treatments.

The increase in moisture content is determined by the gradient of water potential between seeds and atmospheric air. When the potential difference is zero, the water transfer from the surrounding air ceases and the seeds reach hygroscopic equilibrium (Carvalho, 1994).

At the time preceding seed storage (zero days), chemical treatments did not influence the germination regardless of the management zone where the seeds were produced (Figures 3A and 3B). Dan et al. (2010) also reported adequate germination levels for soybean seeds at zero time of storage, using the insecticides Thiamethoxam, Imidacloprid + Thiodicarb and Fipronil in the treatment of seeds.

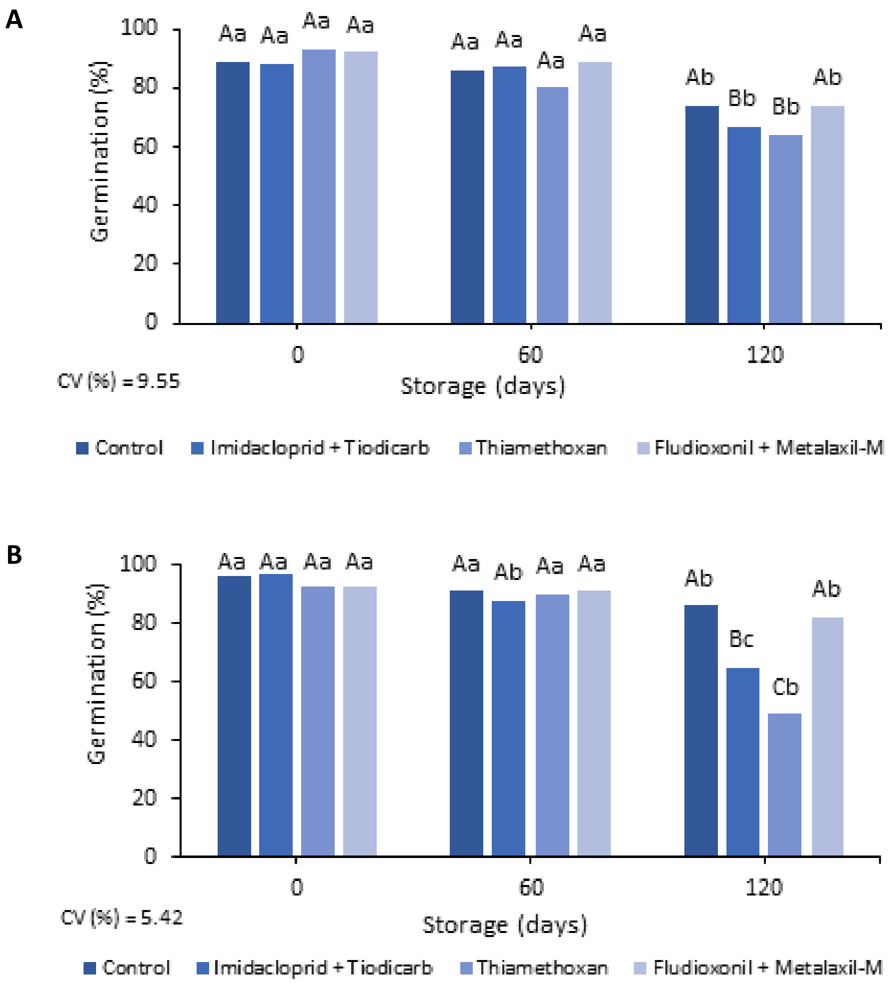


Figure 3. Germination (%) of sorghum seeds produced in high- (A) and low- (B) management zones as a function of seed treatment and storage time. *Means followed by the same uppercase letter for seed treatments and lowercase letter for storage times do not differ from each other by the Scott-Knott test at 5% significance level. CV: coefficient of variation.

Germination of sorghum seeds in the high-management zone was reduced at 120 days of storage when treatments with Imidacloprid + Thiodicarb and Thiamethoxan were performed (Figure 3A). Fessel et al. (2003) observed that the treatment of maize seeds with various insecticides, such as Deltamethrin and Pirimiphos-methyl, caused a negative effect on seed germination, which was intensified with the prolongation of the storage time.

Seeds produced in the low-management zone and treated with Imidacloprid + Thiodicarb and Thiamethoxan also showed a decrease in germination percentage (Figure 3B). However, it was observed that the treatment with Imidacloprid + Thiodicarb, at 60 days of storage, had already caused a decrease in germination. The treatment with Thiamethoxan caused higher toxicity in seeds at 120 days of storage (Figure 3B). The treatments with Imidacloprid + Thiodicarb, Acetamiprid and Thiamethoxan were reported by Carvalho et al. (2020) as causing reductions in soybean germination and development of seedlings, regardless of the time of application of the treatment. This confirms that some insecticide molecules may show toxicity in physiological analyses, mainly in paper substrate (Brzezinski et al., 2015; Ferreira et al., 2016; Santos et al., 2018).

Both in high- and low-production management zones, the treatment of seeds with Fludioxonil + Metalaxyl-M, at 120 days of storage, did not compromise the germination of sorghum seeds, not differing statistically from the control treatment (water) (Figures 3A and 3B). Regarding the percentage of abnormal seedlings, it was observed that in the high-management zone, the seed treatments did not differ statistically at the time preceding storage (Figure 4A).

There was a low percentage of abnormal seedlings evaluated in the germination test. In treatment with Thiamethoxan, it is possible to observe a higher percentage of abnormal seedlings from 60 days of storage, possibly due to toxicity and deterioration of the seeds. Also for the seeds produced in the high-management zone, it can be observed at 120 days that the treatment with Imidacloprid + Thiodicarb had a higher percentage of abnormal seedlings. Rocha et al. (2020) observed that soybean seed treatments with insecticide molecules affect germination and evaluation of seedlings, with higher phytotoxicity compared to fungicide molecules. This occurs mainly in methods of analysis with abundant and readily available water, as is the case of germination in paper. Thus, these authors recommend the use of vermiculite between paper sheets to reduce the effects of phytotoxicity caused by insecticides.

For sorghum seeds produced in the low-management zone and treated with Imidacloprid + Thiodicarb, there was an increase in abnormal seedlings at 60 days of storage, but at 120 days there was no statistical difference from the previous time (Figure 4B). In seeds treated with Thiamethoxan at 120 days of storage, it was possible to observe a higher percentage of abnormal seedlings in the evaluation of the germination test (Figure 4B). This was possibly due to the deleterious effects of deterioration and phytotoxicity. However, it is worth mentioning that beneficial physiological effects through the treatment of seeds with Thiamethoxam were reported by Castro et al. (2008), which promoted the expression of genes related to the synthesis and activity of enzymes, altering the production of amino acids precursors of phytohormones, resulting in increased germination, vigor, and root length.

The treatment with Fludioxonil + Metalaxyl-M did not differ statistically at the storage times (0, 60 and 120 days), for seeds produced both in the high-management zone and in the low-management zone. This reinforces the less aggressive effect of fungicides in terms of phytotoxicity in seed treatment (Rocha et al., 2020).

In relation to infected seedlings, that is, those resulting from fungal infection, it was verified that the seeds from the high-management zone showed a low percentage of infection at the zero time of storage (Figure 5A). However, at 120 days of storage there was greater infection in the control treatments, followed by Imidacloprid + Thiodicarb and Thiamethoxan. The fungi identified were of the genera *Penicillium* and *Aspergillus*, which may compromise the sanitary quality of the stored seeds.

This same behavior was verified at 120 days for sorghum seeds from the low-management zone, when the control treatment and the treatment with insecticides showed a higher percentage of infected seedlings (Figure 5B). At 60 days, the treatments with insecticide already had a higher percentage of seedlings infected with fungi, differing statistically from the other treatments. There was an increase in the percentage of infected seedlings in the control treatment at 120 days of storage, showing the importance of seed treatment with fungicides (Figure 5B). The treatment of seeds

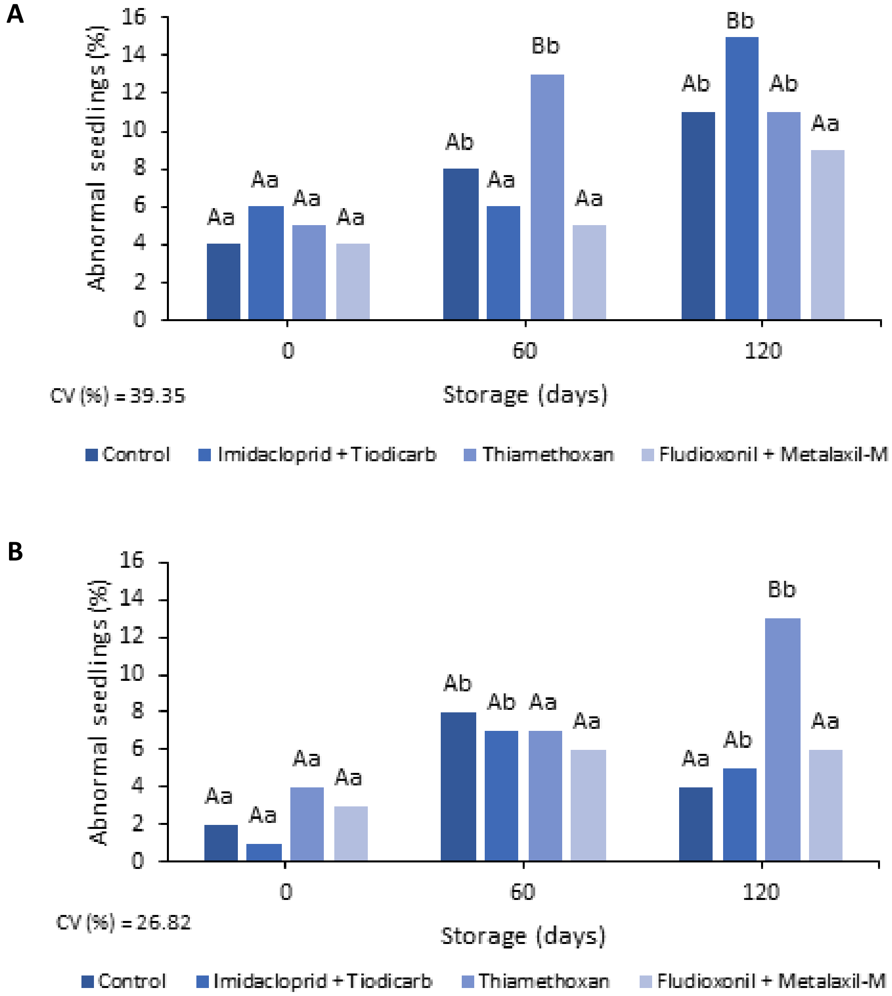


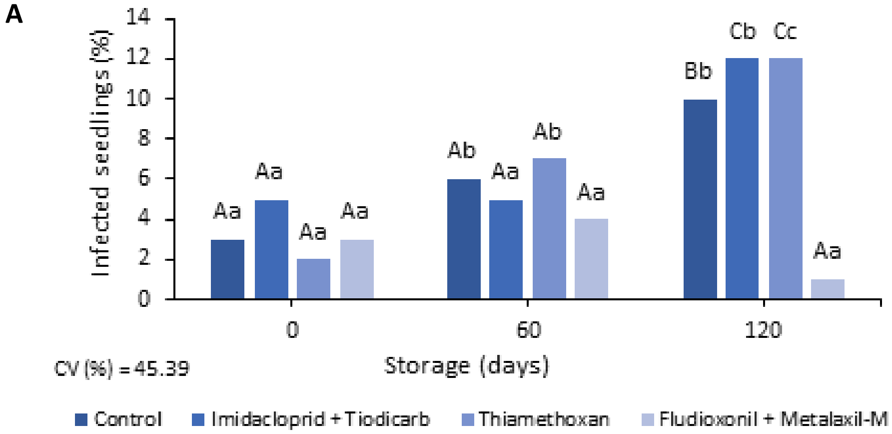
Figure 4. Abnormal seedlings (%) evaluated in the germination test of sorghum seeds produced in high- (A) and low- (B) management zones as a function of seed treatment and storage time. *Means followed by the same uppercase letter for seed treatments and lowercase letter for storage times do not differ from each other by the Scott-Knott test at 5% significance level. CV: coefficient of variation.

with the fungicide Fludioxonil + Metalaxyl-M did not allow the advancement of fungal infection, in seeds produced in the both high-management zone and low-management zone.

It is possible to observe in Figure 5B that, before storage (zero days), the seeds treated with Fludioxonil + Metalaxyl-M led to a higher percentage of seedlings with infection. This result may have occurred because there was no time for the product to cause its fungitoxic effect, because the seed quality evaluations started after 48 hours of treatment. However, it is worth mentioning that, at 120 days of storage, there were no infected seedlings from sorghum seeds from the low-management zone (Figure 5B), pointing to the eradication effect of the fungicide Fludioxonil + Metalaxyl-M.

In relation to the accelerated aging test, there was a reduction in vigor as the storage time progress with chemical treatment (Figures 6A and 6B). The vigor of seeds with Fludioxonil + Metalaxyl-M treatment did not differ from the control treatment in the storage time for both management zones. In seeds from high- and low-management zones treated with Thiamethoxam, it is possible to verify the reduction of vigor from 60 days of storage (Figures 6A and 6B).

However, at 120 days of storage of seeds produced in the low-management zone (Figure 6B), the treatment with Thiamethoxam further reduced seed vigor, differing from other storage times. Dan et al. (2010) reported that, after the treatment of seeds with Carbofuran and Acephate insecticides, there was a reduction in the percentage of normal



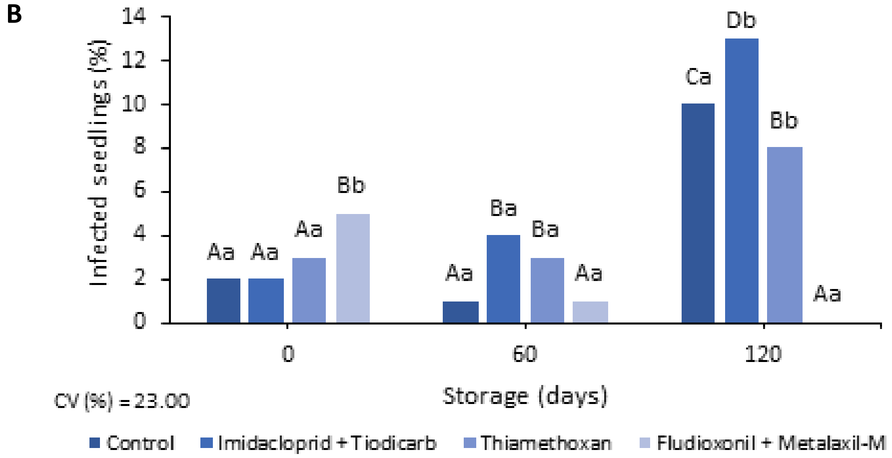


Figure 5. Infected seedlings (%) evaluated in the germination test of sorghum seeds produced in high- (A) and low- (B) management zones as a function of seed treatment and storage time. *Means followed by the same uppercase letter for seed treatments and lowercase letter for storage times do not differ from each other by the Scott-Knott test at 5% significance level. CV: coefficient of variation.

seedlings obtained in the accelerated aging test, which was more evident as the storage days increased. These same authors also showed that, although there were reductions in vigor with the increase in storage time, it was possible to observe levels above 80% in soybean seeds treated with the insecticides Fipronil, Thiamethoxam, Imidacloprid and Imidacloprid + Thiodicarb. In both management zones there were reductions in the vigor of sorghum seeds below this percentage.

According to the electrical conductivity test, at the beginning of the storage time, there was no difference between the treatments for the seeds from the high-management zone (Figure 7A). Seeds treated with Imidacloprid + Thiodicarb showed an increase in electrical conductivity at 60 days when compared to the previous storage time. Seeds treated with the insecticides Imidacloprid + Thiodicarb and Thiamethoxam showed leaching of approximately 150 $\mu S.cm^{-1}.g^{-1}$, differing from the control and Fludioxonil + Metalaxyl-M treatments (Figure 7A). This indicates the deleterious effect of insecticides on seeds, contributing to the reduction of vigor. According to Horii et al. (2007), decreases in the viability and vigor of seeds treated with insecticides can be attributed to the low integrity of membranes.

As shown in Figure 7B, at the zero time of storage, the electrical conductivity of the seeds was higher in the treatments with Thiamethoxam and Fludioxonil + Metalaxyl-M. There was also a statistical difference at 60 days of

A

B

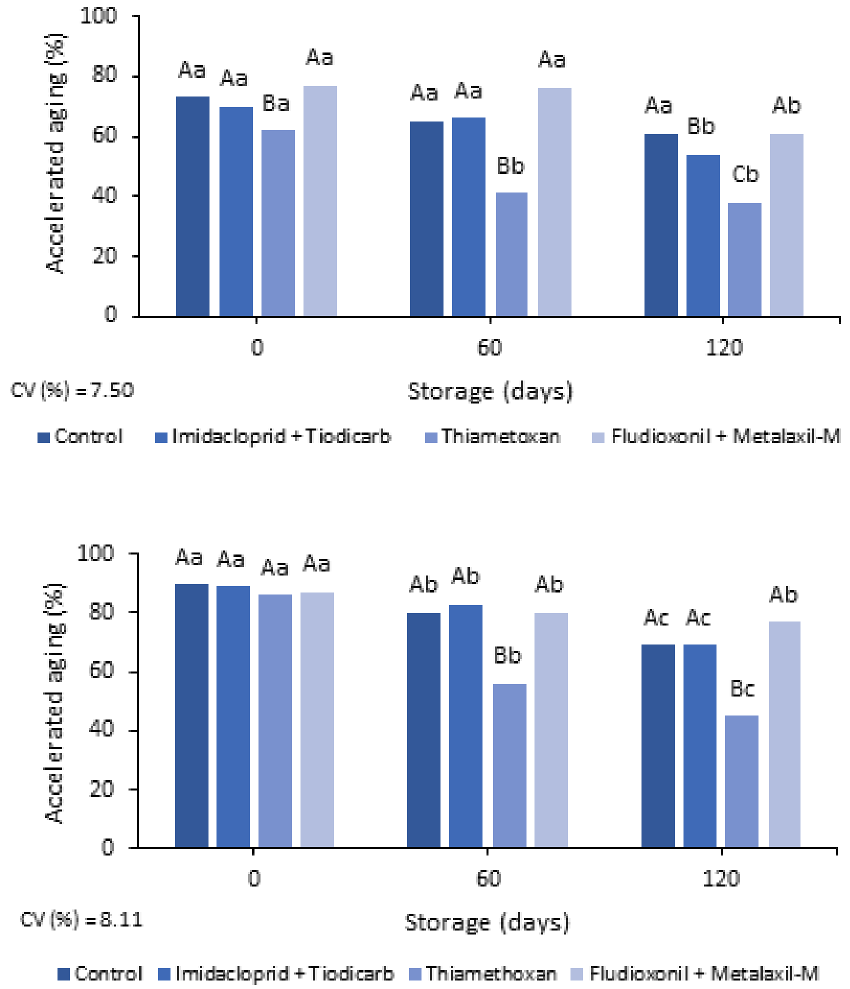


Figure 6. Accelerated aging (%) of sorghum seeds produced in high- (A) and low- (B) management zones as a function of seed treatment and storage time. *Means followed by the same uppercase letter for seed treatments and lowercase letters for storage times do not differ from each other by the Scott-Knott test at 5% significance level. CV: coefficient of variation.

storage, when the control treatment had the lowest electrical conductivity, followed by the treatments with Fludioxonil + Metalaxyl-M, Thiamethoxam and Imidacloprid + Thiodicarb. At 120 days of storage, only the treatment with Fludioxonil + Metalaxyl-M differed from the others. The treatments with insecticides and control showed leaching of approximately 200 $\mu S.cm^{-1}.g^{-1}$, indicating a lower seed vigor (Figure 7B). The higher electrical conductivity of the control treatment may possibly be attributed to storage fungi.

High values of electrical conductivity may indicate that the seeds may be in a larger process of deterioration. On the other hand, low values indicate that seeds have high physiological quality, as the cell membranes are organized or have the ability to reorganize, indicating a less intense deterioration process (Marcos-Filho, 2015). It is worth pointing out that the treatment of seeds does not contribute to the increase of leachates in the electrical conductivity test. Similarly, Vazquez et al. (2014) found that maize seed treatments with Imidacloprid + Thiamethoxam, Fludioxonil + Metalaxyl-M, among other insecticides and fungicides, did not interfere in the results of the electrical conductivity test.

Regarding the dry mass of seedlings, there was no significant difference between the treatments of seeds from the high-management zone at the zero time of storage (Figure 8A). However, the seeds of the control treatment, at 120

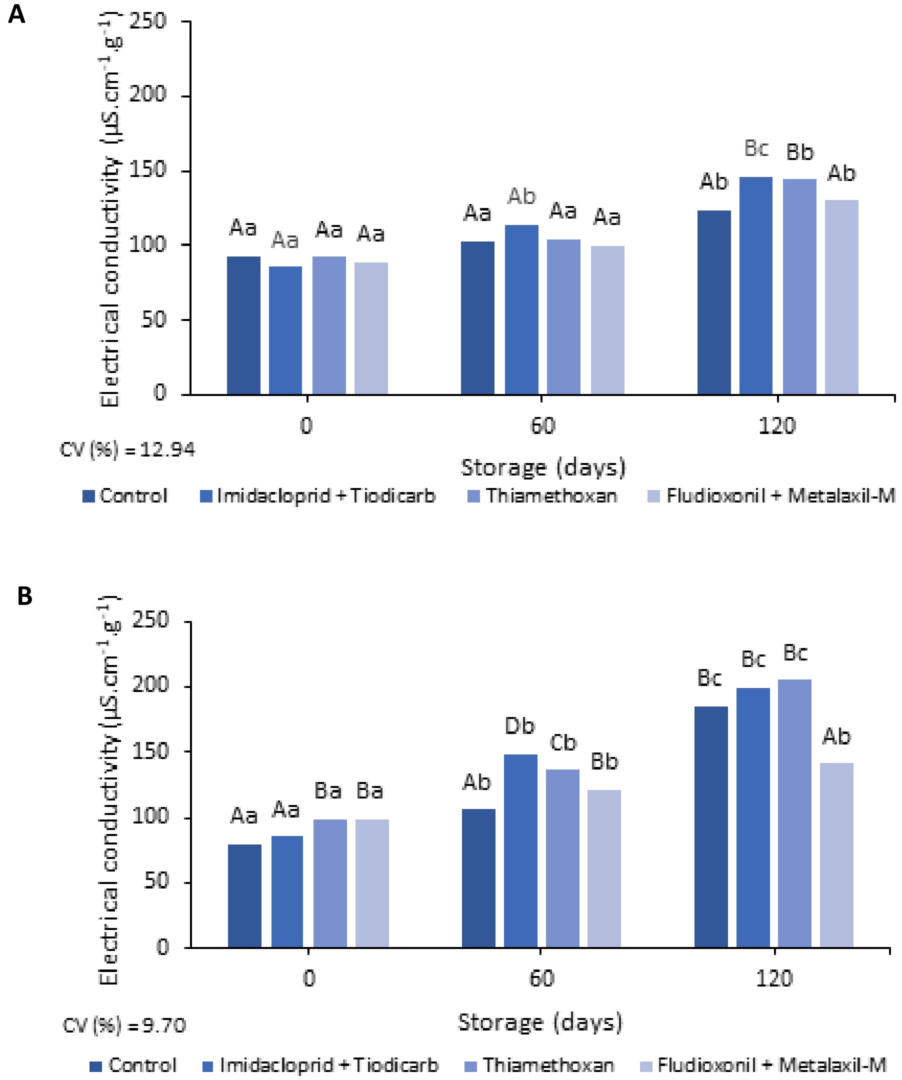


Figure 7. Electrical conductivity (µS.cm^{-1}.g^{-1}) of sorghum seeds produced in high- (A) and low- (B) management zones as a function of seed treatment and storage time. *Means followed by the same uppercase letter for seed treatments and lowercase letter for storage times do not differ from each other by the Scott-Knott test at 5% significance level. CV: coefficient of variation.

days of storage, led to higher dry mass, followed by the treatments with Imidacloprid + Thiodicarb and Fludioxonil + Metalaxyl-M, which did not differ. The treatment with thiamethoxam showed the lowest dry mass of seedlings.

In Figure 8B, referring to the low-management zone, seedlings from seeds treated with Imidacloprid + Thiodicarb had higher dry mass at the zero time of storage, differing from those of the other treatments. However, there was a 42% decrease in the dry mass of seedlings from sorghum seeds treated with this insecticide at 60 days of storage. It is also worth mentioning that the dry mass decreased by 58% at 120 days of storage. In the treatment with Thiamethoxam, the reduction in the dry mass of seedlings was equal to 45% at 60 and 120 days storage. Ludwig et al. (2011) reported a 26% reduction in the dry mass of seedlings grown from soybean seeds treated with fungicides and insecticides and stored for up to 120 days, and this reduction was in the capacity of translocation of seed reserves to the embryo (Pereira et al., 2018).

In general, treatments with the insecticides Imidacloprid + Thiodicarb and Thiamethoxam compromised the quality of sorghum seeds from 60 days of storage, with reductions in germination and vigor for both management zones. It is worth pointing out that the highest moisture contents were verified in these treatments, which contributed to the increase in seed respiration, promoting higher consumption of reserves and accelerating the deterioration process. It is also emphasized that there was a decrease in germination, reduction of vigor evaluated by the accelerated aging test and increase in electrical conductivity, indicating changes in the membrane system. All these manifestations are due to seed deterioration and can be intensified by the effect of phytotoxicity. Thus, Zambon (2013) and Strieder et al. (2014) recommended performing the soybean seed treatment process no later than 60 days before the beginning of sowing, to minimize possible toxic effects on the plants caused by the mixtures applied to the seeds.

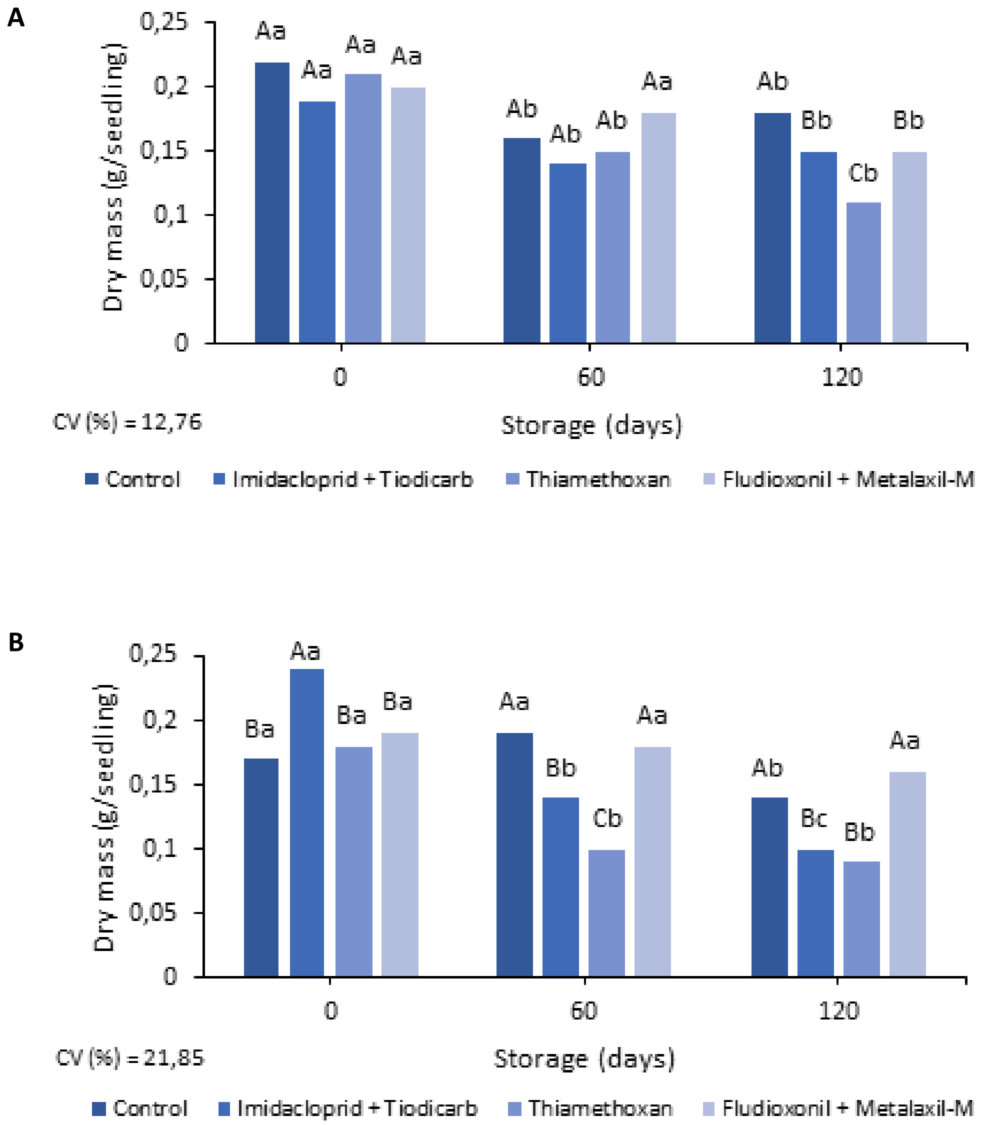


Figure 8. Dry mass of seedlings (g/seedling) of sorghum seeds produced in high- (A) and low- (B) management zones as a function of seed treatment and storage time. *Means followed by the same uppercase letter for seed treatments and lowercase letter for storage times do not differ from each other by the Scott-Knott test at 5% significance level. CV: coefficient of variation.

CONCLUSIONS

Sorghum seed treatments with insecticides cause greater phytotoxicity during storage in both management zones, as opposed to the fungicide treatment. Sorghum seeds produced in high-management zones have high physiological quality and with less deterioration during storage. Sorghum seeds produced in low-management zones treated with insecticides, as the storage time increase, show lower vigor due to deterioration and phytotoxicity.

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