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Qualidade fisiológica das sementes de sorgo granífero durante o armazenamento

Physiological quality of graniferous sorghum seeds during storage

Calidad fisiológica de semillas de sorgo granífero durante el almacenamiento

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Resumo

O presente trabalho objetivou avaliar o efeito de diferentes temperaturas de secagem e tempos de armazenamento na qualidade fisiológica de sementes de sorgo granífero. As sementes foram colhidas manualmente após a maturação, com teor de água de aproximadamente 21% b.u., no município de Jataí - GO, Brasil. Em seguida foram então secas em estufa de circulação de ar forçado a temperaturas controladas de 40, 50, 60 e 70 °C até um teor final de água de 12 ± 1% b.u.. As sementes foram armazenadas em embalagens de papel Kraft por seis meses em condições de laboratório e avaliadas quanto ao: teor de água, condutividade elétrica, emergência na areia, índice de velocidade de emergência, comprimento de plântulas, matéria seca de plântulas e envelhecimento acelerado. Parâmetros como emergência, envelhecimento acelerado e comprimento de plântulas diminuíram ao longo do armazenamento, enquanto a condutividade elétrica aumentou com o tempo.

Palavras-chave: *Sorghum bicolor*; Secagem; Teor de água.

Abstract

The present study aimed to evaluate the effect of different drying temperatures and storage times on the physiological quality of graniferous sorghum seeds. Graniferous sorghum seeds were manually harvested after maturation, with moisture content of approximately 21% d.b., in the municipality of Jataí – GO, Brazil. The seeds were then dried in a forced air circulation oven at controlled temperatures of 40, 50, 60 and 70 °C until a final moisture content of 12 ± 1% d.b.. The seeds were stored in kraft paper packages for six months under laboratory conditions and evaluated for: moisture content, electrical conductivity, emergence in sand, emergence speed index, seedling length, seedling dry matter and accelerated aging. Parameters such as emergence, accelerated aging and seedling length decreased along storage, whereas electrical conductivity increased over time.

Keywords: *Sorghum bicolor*; Drying; Moisture content.

Resumen

El presente estudio tuvo como objetivo evaluar el efecto de diferentes temperaturas de secado y tiempos de almacenamiento en la calidad fisiológica de las semillas de sorgo granífero. Las semillas se cosecharon manualmente después de la maduración, con un contenido de agua de aproximadamente 21% b.h., en el municipio de Jataí - GO, Brasil. Luego se secaron en un horno de circulación de aire forzado a temperaturas controladas de 40, 50, 60 y 70 ° C hasta un contenido final de agua de 12 ± 1% b.h. Las semillas se almacenaron en envases de papel Kraft durante seis meses. Bajo condiciones de laboratorio y evaluado para: contenido de agua, conductividad eléctrica, emergencia en la arena, índice de velocidad de emergencia, longitud de la plántula, materia seca de la plántula y envejecimiento acelerado. Parámetros como la emergencia, el envejecimiento acelerado y la longitud de las plántulas disminuyeron durante el almacenamiento, mientras que la conductividad eléctrica aumentó con el tiempo.

Palabras clave: *Sorghum bicolor*; Secado; Contenido de agua.

1. Introduction

The seed is considered as the most important agricultural input because it is the starting point of the entire production chain. In this context, there is a great technological advance developed by means of studies and research aiming at new improved cultivars that meet all marketing requirements and that can meet consumer needs (Carvalho et al., 2016).

In the choice on the ideal seed, a series of characteristics must be considered by the rural producer, including the production capacity. To achieve high yield, it is necessary to obtain a material that has adequate physiological quality. One of the essential tools to obtain these results is the analysis of seeds. Evaluating the quality of a lot in terms of estimating how successful the seeds will be at establishing an adequate stand of seedlings in the field, under a wide range of environmental conditions, is of great importance to achieve efficiency in modern agriculture (Arthur & Tonkin, 1991).

Physiological quality has been studied because seeds may undergo degenerative alterations of biochemical, physical and physiological origin after being removed from the field, which compromise certain parameters, especially their vigor. Thus, seed quality is related to the degree of varietal purity, vigor and health. This set of characteristics combined to other management practices, such as fertilization, phytosanitary control, water availability, among others, are determinant in the success of crops of economic importance (Binotti et al., 2008).

After harvest in the field, seeds are usually subjected to drying and then to storage until the material is marketed. In this post-harvest step, factors such as initial and storage moisture contents, drying temperature, air temperature and relative humidity and the characteristics which are intrinsic to the seeds, are decisive in the maintenance of quality over time (Kong et al., 2008; Malaker et al., 2008).

It is known that the deterioration of plant materials cannot be completely avoided because, throughout the storage time, agricultural products tend to lose quality due to respiration (Smaniotto et al., 2014). However, with adequate management practices during post-harvest steps, such deterioration process may be minimized, contributing to the longevity of the material and resulting in greater stability of quality.

Several tests are conducted to predict the effect of these factors on seed vigor, contributing to the formation of lots with similar characteristics and that can originate healthy seedlings which are adequate for establishment in the field.

In addition to these physiological responses, knowledge on the hygroscopicity of seeds is of extreme importance because these materials have the capacity to absorb and release water to the storage environment, tending to equilibrium. By using such research tool it is possible to define adequate moisture contents to prevent the beginning of microbial activity and the drying limits of the product that will be sent for storage (Ullmann et al., 2016).

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Given the above, this study aimed to evaluate the effect of different drying temperatures and storage times on the physiological quality of graniferous sorghum seeds.

2. Methodology

The present study represents research applied at the laboratory level, in which the quantitative method was used to evaluate the data, the research methodology was classified according to the guidelines of Pereira et al. (2018). This method aims to generate mathematical equations that represent the variation of the analyzed processes according to the treatments.

2.1. Drying and storage of seeds

Experiment used seeds of graniferous sorghum (DKB 550 hybrid) manually harvested after maturation, with moisture content of approximately 21% (d.b.), in the municipality of Jataí – GO, Brazil. After harvest, the seeds were dried in a forced air circulation oven at controlled temperatures of 40, 50, 60 and 70 °C.

Seeds were dried on trays without holes containing 0.4 kg of product spread in a 4-cm-thick layer, in four replicates, totaling 1.6 kg of product for each treatment. The trays were periodically weighed until the final point of drying, 12 ± 1% (d.b.). Air temperature and relative humidity in the drying room were monitored by means of a data logger.

The seeds were stored in kraft paper packages for six months, maintained under laboratory conditions. During storage, air temperature and relative humidity were recorded by a digital data logger.

Samples were evaluated every 60 days (0, 60, 120 and 180 days of storage), in three replicates, with respect to moisture content, electrical conductivity, emergence in sand, emergence speed index, seedling length, seedling dry matter and accelerated aging.

2.2. Moisture content and physiological seed quality

Moisture content was determined by gravimetry in an oven at 105 °C, for 24 hours (Brasil, 2009), with modifications, in three replicates.

The electrical conductivity test was carried out according to the methodology described by Vieira & Krzyzanowski (1999). Fifty seeds were used for 4 subsamples of each treatment, soaked in plastic cups containing 75 mL of deionized water and maintained in B.O.D. type chamber at controlled temperature of 25 ºC, for 24 hours. The solutions containing the products were slightly shaken to uniformize the leachates, followed by immediate reading in a portable digital conductivity meter, and the results were divided by the mass of the product and expressed in µS cm^{-1} g^{-1} of seeds.

The emergence test was conducted with four replicates of 50 seeds from each treatment, which were sown in a sand bed in a greenhouse with intermittent spraying three times a day, containing coarse sand as substrate, at 2 cm depth, according to Nakagawa (1999).

At emergence, emerged seedlings were considered as those with leaf primordia at 1 cm from the substrate, which were counted from the 1st to the 14th day after sowing (DAS), when total emergence – EM (at 14 DAS) and emergence speed index (ESI), calculated according to Maguire (1962), were evaluated.

Seedling length was evaluated in 4 subsamples of 20 seeds in alternated rows for each lot, in Germitest paper rolls moistened with distilled water, using a volume equivalent to 2.5 times the dry substrate weight. The rolls were placed in plastic bags vertically arranged in a B.O.D. chamber for 10 days at 25 ºC. After this period, the parts of the emerged normal seedlings (primary root and hypocotyl) were measured using a ruler. The average results per seedling were expressed in centimeters (Nakagawa, 1999).

The dry matter of normal seedlings (DM) was evaluated along with seedling growth, by placing these seedlings in kraft paper packages and taking them to a forced air circulation oven, maintained at temperature of 65 ºC for 72 h. The obtained mass was divided by the number of seedlings composing the subsample to obtain the average dry matter per seedling. The arithmetic mean of the four subsamples evaluated represented the seedling dry matter of the treatment (Nakagawa, 1994).

The accelerated aging test was conducted using the procedure proposed by AOSA (1983) and described by Marcos Filho (1999). Initially, 200 seeds were distributed on a screen attached to a box (Gerbox) containing 40 mL of distilled water. The boxes were covered and kept for 72 hours in B.O.D chamber at temperature of 41 °C. After the period of exposure, 4 replicates of 50 seeds were subjected to the germination test, as described by Brasil (2009). The results were expressed in percentage of normal seedlings obtained from the 4th to the 10th day after sowing.

2.3. Statistical analysis

The experiment was set up in a 4 x 4 scheme in split plots, with four temperature (40, 50, 60 and 70 °C) and four storage times (0, 2, 4 and 6 months), in a completely randomized design, with three replicates. The data were assessed by analyses of variance and regression. The models were selected based on the significance of the equation by F test, on the significance of regression coefficients by t-test, at 0.05 significance level, on the coefficient of determination (R^2 or r^2 for simple linear regression) and on the knowledge about the evolution of the biological phenomenon.

3. Results and Discussion

As described in Table 1, the interaction between different drying temperatures and storage times had significant effect only on the biometric parameters root length and seedling length, which were also the only variables affected by drying temperatures. Conversely, the other variables analyzed showed differences between the storage times.

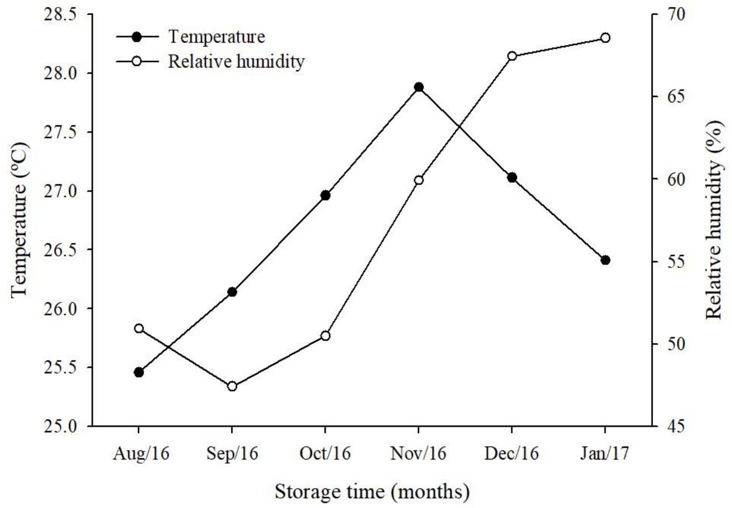
Table 1. Summary of analysis of variance for moisture content (MC), emergence (EM), emergence speed index (ESI), electrical conductivity (EC), accelerated aging (AA), seedling length (SL), root length (RL) and dry matter (DM). The sources of variation are: temperature (T), storage times (St) and the interaction (T x St) between treatments.

		Mean square							
SV	DF	MC	EM	ESI	EC	AA	SL	RL	DM
T	3	$5x10^{-6\ ns}$	6.84^{ns}	0.526^{ns}	24.09^{ns}	5.10^{ns}	11.58^{**}	6.36^{**}	$1357x10^{-3ns}$
St	3	$994x10^{-4\ **}$	83.06^{**}	21.37^{**}	2430.23^{**}	71.69^{*}	427.36^{**}	254.01^{**}	$1075x10^{-2**}$
T x St	9	$6x10^{-6\ ns}$	2.93^{ns}	0.353^{ns}	12.96^{ns}	4.17^{ns}	2.68^{**}	2.32^{**}	$1542\ x10^{-3ns}$
CV_1(%)		2.92	6.01	10.88	13.88	5.91	4.70	9.51	22.22
CV_2(%)		3.32	5.74	7.80	11.38	5.18	6.97	10.03	17.15
Error 1		$11x10^{-4}$	23.75	1.58	21.31	19.91	0.43	0.46	0.0017
Error 2		$15x10^{-4}$	21.65	0.81	14.33	15.33	0.96	0.51	0.0010

** Significant at 0.01 level, * Significant at 0.05 level and ^{ns} Not significant by F test.
Source: Author (2020)

Figure 1 shows the temperature and relative humidity values of the storage environment in which the seeds were stored. The behavior of the storage environment in the months from August 2016 to January 2017 is shown in Figure 1. The evaluations were carried out at the four storage times (0, 2, 4 and 6), which coincided with the months of July, September, November and January, respectively. The overall means of temperature and relative humidity along the six months of storage were 26.66 °C and 57.46%, respectively.

Figure 1. Data of temperature (°C) and relative humidity (%) in the environment of storage of graniferous sorghum seeds.



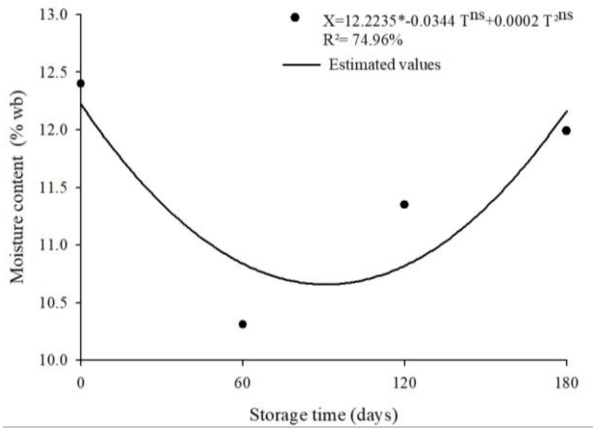
Source: Author (2020)

The behavior of the storage environment in the months from August 2016 to January 2017 is shown in Figure 1. The evaluations were carried out at the four storage times (0, 2, 4 and 6), which coincided with the months of July, September, November and January, respectively. The overall means of temperature and relative humidity along the six months of storage were 26.66 °C and 57.46%, respectively.

Air temperature increased from August to November and decreased until January 2017 (Figure 1). The relative air humidity of the environment increased along the storage time, due to the period of rains which occurred in late October 2016 and extended up to January of the next year.

The figure 2 shows the water content values of the sorghum seeds stored for 180 days. There was a sharp reduction in the moisture contents of graniferous sorghum seeds at 60 days, a behavior that changed at 120 days and remained increasing until the end of the storage.

Figure 2. Moisture content of graniferous sorghum seeds stored in 180 days.

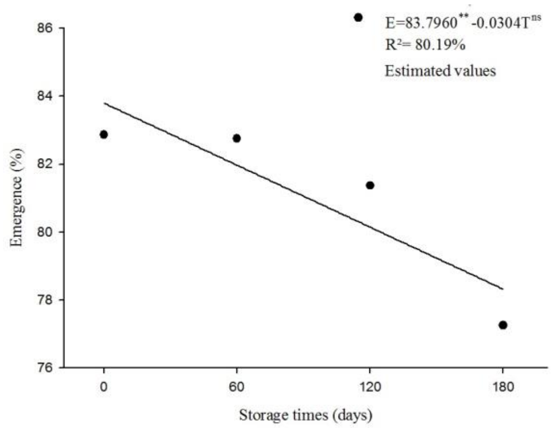


*Significant at 0.05level by t-test; nsnot significant. Source: Author (2020)

It is known that seeds are able to equilibrate with the surrounding microclimate and, for that, they may lose or absorb water. Thus, the alterations observed in the moisture content of sorghum seeds (Figure 2) along the 180 days of storage are due to climatic changes of the environment, involving oscillations of temperature and relative air humidity, besides high permeability of the kraft paper package, which allows exchanges of water vapor between seeds and the external environment, as described in Figure 1.

The percentage of emergence of normal seedlings of the seeds stored for 180 days is included in figure 3.

Figure 3. Data of normal seedlings evaluated by the Emergence test originated from graniferous sorghum seeds stored in kraft paper bags for 180 days.



**Significant at 0.01 level by t-test; nsnot significant. Source: Author (2020)

Regarding the percentage of seedlings evaluated during the emergence in greenhouse (Figure 3), it can be observed that there as a reduction in the values over time. Drying practice can cause cracks in the seeds, which are observed along the storage (latent effect).

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These damages result in a reduction of physical and physiological quality and may reduce the percentage of emerged seedlings. Such reduction along the storage period can also be attributed to a deterioration process due to respiration, in which seeds use their energy reserves to maintain their propagation structures healthy until the germination process is triggered (Menezes et al., 2012).

Storage of seeds in environments in which they are exposed to high air temperatures contributes to the intensification of respiration, for accelerating their metabolism and enzymatic activity due to the availability of water for these reactions to occur. Thus, the longer the storage time under unfavorable conditions, the greater and more intense the deterioration, culminating in a reduction in the vigor of the germination structures of the seeds, leading to reduced formation of viable seedlings.

Zucareli et al. (2015), who evaluated *Carioca* beans in different environments, observed that, for the effect along the periods, the increase in storage time reduced seedling emergence in the field in both environments tested (dry chamber and natural environment), but there was higher reduction rate for the storage under uncontrolled conditions.

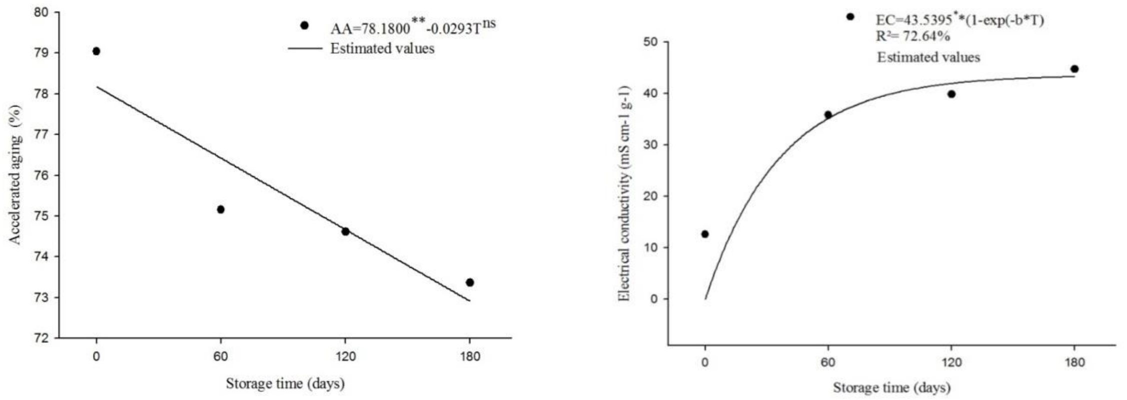
Oliveira et al. (2011), working with two sorghum cultivars, obtained different results. These authors found increment in the percentage of emergence in the sixth month of storage and suggested that it occurred due to the reduction in the percentage of dormant seeds.

The values found for emergence speed index were 10.45, 10.44, 13.03 and 12.40% at the storage times of 0, 60, 120 and 180 days, respectively.

There was a linear increase in the germination percentage of seeds exposed to accelerated aging along the storage period (Figure 4A).

Figure 4. Accelerated aging (A) and electrical conductivity (B) of graniferous sorghum seeds stored in kraft paper bags for 180 days.

A) B)



**Significant at 0.01 level by t-test; *Significant at 0.05level by t-test. Source: Author (2020)

The accelerated aging considers the true germination potential of seeds subjected to abiotic stress conditions, allowing one to know the actual vigor. This is because the most vigorous seeds have more efficient mechanisms of repair, especially due to the action of antioxidant molecules, such as the peroxidases, superoxide dismutase and catalase (Marcos Filho, 2015). Fujikura & Karssen (1995) report that seed deterioration tends to increase with the increments in temperature and relative humidity, causing damage to membranes, proteins and nucleic acids.

Araujo et al. (2017), working with Leucaena seeds, and Zucareli et al. (2015), in a study with *Carioca* bean seeds, found results similar to those obtained in this work, confirming that storage time can reduce the germination of seeds exposed to accelerated aging. Rocha et al. (2017), corroborating with the other authors, observed a 12% reduction in the germination of soybean seeds exposed to the test during 120 days of storage.

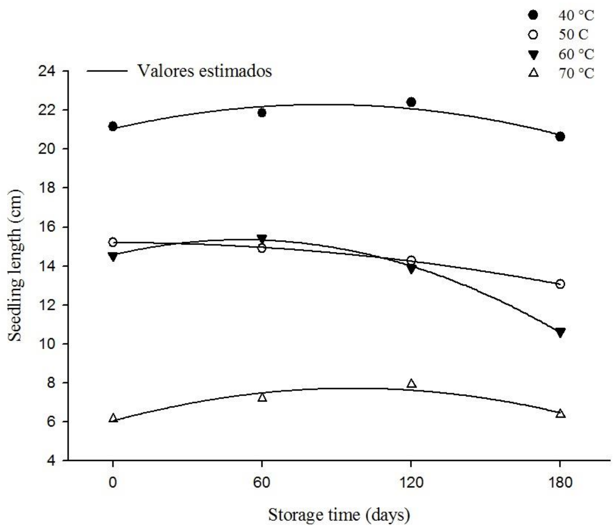
According to Figure 4B, there is an increasing behavior in the electrical conductivity of graniferous sorghum seeds throughout the storage period. The mean values found were 12.62, 35.82, 39.85 and 44.74 mS cm^{-1} g^{-1} at the times of 0, 60, 120 and 180 days, respectively.

Ullmann et al. (2015), studying the drying of sweet sorghum, report that the increase in electrical conductivity expresses greater disorganization of seed membrane cells, making them more susceptible to external damage, such as environmental conditions and pathogenic actions, causing severe physiological damage and affecting seed vigor. In this context, the increment observed in the present study probably occurred due to increased leaching of electrolytes resulting from minor damages caused in seed structure throughout the storage time. These minor damages may have been caused by the air temperature and relative humidity in the environment, causing greater absorption and reduction of moisture content and action of microorganisms.

Silva et al. (2010), Zuchi et al. (2013) and Smaniotto et al. (2014), working with soybean, and Zucareli et al. (2015), working with beans, also found similar results, reinforcing that storage can contribute to the increase in the electrical conductivity of seeds.

For seedling length, there was effect of the interaction between drying air temperature and storage times (Figure 5).

Figure 5. Seedling length of graniferous sorghum seeds stored in kraft paper bags for 180 days.



Source: Author (2020)

Seedling length was strongly affected by the highest drying temperatures (Figure 5), which caused reduction of growth, whereas lower temperatures allowed greater development. The maximum points of the curves were 22.09, 12.53, 15.31 and 7.54 cm for the temperatures of 40, 50, 60 and 70 °C, respectively. In relation to the storage time, a slight reduction was observed only in the final period.

Table 2 shows the quadratic equations adjusted to the values obtained in the evaluation of seedling length the graniferous sorghum seeds storage.

Table 2. Quadratic equations fitted to the values obtained in the evaluation of length of seedlings (cm) grown from graniferous sorghum seeds stored in kraft paper bags for 180 days.

Temperature °C	Equations	R^2
40	$SL=21.0520^{*}+0.0289T^{ns}-0.0002T^{2ns}$	87.07%
50	$SL=15.1900^{**}-8.3333T^{ns}-6.5278T^{2ns}$	99.93%
60	$SL=14.5690^{**}+0.0299T^{ns}-0.0003T^{2ns}$	99.77%
70	$SL=6.0530^{*}+0.0345T^{ns}-0.0002T^{2ns}$	90.34%

**Significant at 0.01 level by t-test; *Significant at 0.05level by t-test; ^{ns}not significant. Source: Author (2020)

Oliveira et al. (2015) observed similar behavior evaluating cowpea seeds stored for 180 days and reinforce that, as storage advances, damages to seed vigor occur due to the natural process of deterioration, which is inevitable and irreversible.

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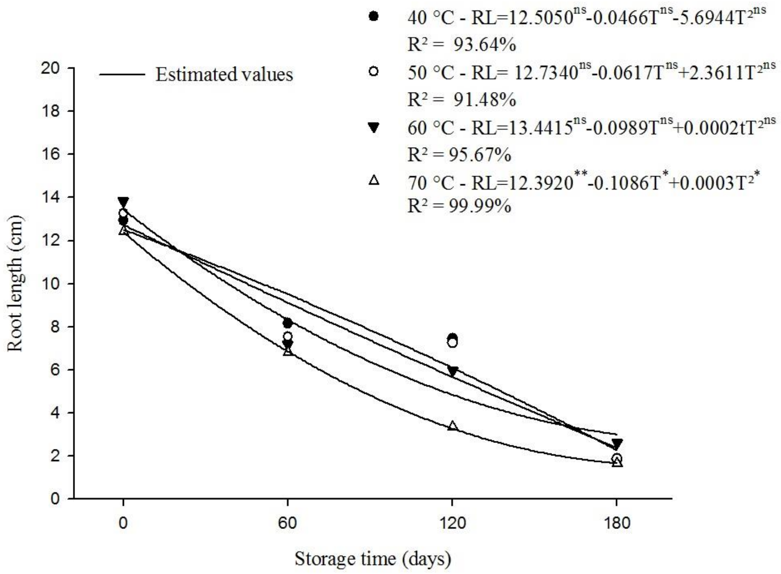
Azevedo et al. (2003), analyzing the influence of packaging and storage conditions on sesame seeds, observed that the storage in a natural environment carried out in kraft paper bags (permeable packaging) causes more accentuated reductions in seed viability along storage, due to greater influence of climatic conditions, causing expressive reduction of quality.

Figure 6 represents the root length of seedlings growing from stored graniferous sorghum seeds.

Figure 6. Root length of seedlings grow from graniferous sorghum seeds stored in kraft paper bags for 180 days.



**Significant at 0.01 level by t-test; *Significant at 0.05level by t-test; nsnot significant. Source: Author (2020)

For root length, it is possible to observe that the interaction between the evaluated factors significantly affected the development of the root organ (Figure 6), high drying temperatures reduced root length, and such deleterious effect became more intense as storage progressed.

This demonstrates that root system formation is damaged when seeds are dried at excessively high temperatures and that this effect is intensified in stored seeds.

The dry matter of seedling from stored graniferous sorghum seeds is represented by the quadratic equation in figure 7.

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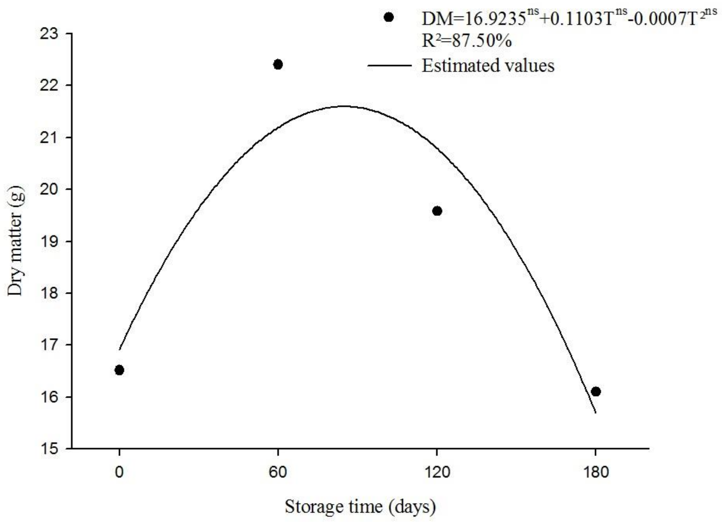
Figure 7. Dry matter of seedlings grown from graniferous sorghum seeds stored in kraft paper bags for 180 days.



[ns]not significant by t-test. Source: Author (2020)

For the dry matter of normal seedlings of graniferous sorghum in the figure 7, it can be noted that there was a maximum point in the curve of 21.27 g of dry matter at 79 days of storage and, after that period, the values decreased and such reduction remained until the end of the storage (Figure 7). This decrease results from the reduction in seedling development, as can be confirmed in Figures 5 and 6.

These biometric and biomass parameters, along with the other tests of vigor, demonstrate the signs of seed deterioration throughout the storage period, disfavoring the formation of viable seedlings due to the loss of quality. Bewley et al. (2013) report that these declines in vigor are the result of seed deterioration due to aging and of the destructuring of the membrane system and loss of permeability due to the attack of its cellular constituents by free radicals.

4. Final Considerations

Graniferous sorghum seeds dried at high temperatures and/or stored for a long time lose their physiological quality.

High drying temperatures result in damage to root formation and length of sorghum seedlings.

Emergence percentage of sorghum seeds decreases along the storage time, and a strong reduction can be observed after 120 days of storage.

Electrical conductivity greatly increases from 60 days of storage, and such increasing behavior of its values continues up to 180 days.

Storage under natural environment conditions reduces the physiological quality and vigor of the seeds with respect to all the characteristics evaluated, and the effects of deterioration can be observed already at 60 days.

Sorghum seeds should not be stored in permeable packages under natural conditions for a period longer than 60 days.

To define a better post-harvest processing method for sorghum seeds, further research can be carried out in different storage environments.

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