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Research Article

Physiological quality of maize seeds treated and stored at different temperatures

Qualidade fisiológica de sementes de milho tratadas e armazenadas sob diferentes temperaturas

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ABSTRACT

Treatment of corn seeds is a common practice in seed processing units since the productive success of crops depends on the use of high-quality seeds. The control of deterioration in storage ensures the maintenance of the germination capacity and vigor of the seeds, allowing them to tolerate adverse factors when sown in the field. The objective of this study was to analyze the quality of corn seeds treated and stored at different temperatures. Corn seeds of AL Bandeirante variety were subjected to chemical treatment with insecticides (based on Actellic 500 CE + K-obiol + Maxim X) and stored at temperatures of 10°C, 18°C and 26°C. At 0, 30, 60 and 90 days, seed performance was evaluated in split-plots in time with four replications by means of moisture content, germination percentage, sand emergence percentage and accelerated aging test. The percentage of seed germination remained within the commercialization standards for up to 90 days of storage at temperatures of 10ºC, 18ºC and 26ºC. However, the evaluation of vigor from the percentage of seedling emergence and percentage of germination after accelerated aging reduced with the advance of seed conservation, indicating changes in vigor due to storage temperature.

KEYWORDS: *Zea mays.* Seed conservation. Germination. Vigor test.

RESUMO

O tratamento de sementes de milho é uma prática comum nas unidades de beneficiamento de sementes, visto que o sucesso produtivo das lavouras depende da utilização de sementes de alta qualidade. O controle da deterioração no armazenamento, garante a manutenção da capacidade de germinação e vigor das sementes, permitindo que sejam capazes de tolerar fatores adversos quando semeadas no campo. O objetivo do trabalho foi analisar a qualidade de sementes de milho tratadas e armazenadas sob diferentes temperaturas. Sementes de milho da variedade AL Bandeirante foram submetidas ao tratamento químico com inseticidas (a base de Actellic 500 CE + K-obiol + Maxim X) e armazenadas nas temperaturas de 10 °C, 18 °C e 26 °C. Aos 0, 30, 60 e 90 dias o desempenho das sementes foi avaliado em parcelas subdivididas no tempo com quatro repetições por meio do teor de umidade, porcentagem de germinação, porcentagem de emergência em areia e teste de envelhecimento acelerado. A porcentagem de germinação das sementes se manteve dentro dos padrões de comercialização por até 90 dias de armazenamento nas temperaturas de 10 ºC, 18 ºC e 26 ºC. No entanto, a avaliação do vigor a partir da porcentagem de emergência das plântulas e da porcentagem de germinação após o envelhecimento acelerado, foram reduzidas com o avanço da conservação das sementes, indicando alterações no vigor devido à temperatura de armazenamento.

PALAVRAS-CHAVE: *Zea mays.* Conservação de sementes. Germinação. Teste de vigor.

INTRODUCTION

Corn (Zea mays L.) is an annual plant belonging to the Poaceae family with great socioeconomic importance, considered one of the main agricultural commodities, widely used in industry, human and animal food (EMBRAPA 2021).

The success of corn crops depends directly on the use of good quality seeds and to achieve the production of high standard seeds, it is necessary to implement a quality control program. The quality control of corn seeds has been increasingly highlighted for their efficiency, resulting in an increase in investments in the area due to the competitiveness of the market (ESPINDOLA et al. 2018).

Several factors can affect seed quality, such as the production method, harvesting, processing, and storage (MAIA et al. 2020). Among the most evaluated seed quality attributes, the genetic purity stands out, which is related to the presence or absence of other varieties in the same seed lot; sanitary quality involving the presence of pathogens, pest attacks and diseases in the seeds; physical purity, referring to the percentage of seeds of other species and inert materials in the seed lot in consideration; and the physiological quality related to the seed's ability to express its germination potential and vigor (KRZYZANOWSKI et al. 2018). All these attributes can be evaluated through laboratory or field tests.

The germination test is conducted in the laboratory with controlled conditions of temperature, humidity and light, allowing the seeds to manifest their maximum potential. However, this test is limited to predict performance in the field, as environmental conditions are not always ideal. Vigor reduction occurs before germination reduction, which means that seed lots with similar germination rates may have different levels of vigor, thus affecting seedling performance in the field (MARCOS FILHO 2020).

Seed storage is a crucial step that precedes sowing and analyzing the deterioration of seeds throughout the conservation period allows prior knowledge on seed quality, since storage conditions exert a significant influence on the physiological quality of the seed lot, especially regarding thermal conditions (MARCOS FILHO 2015).

The increase in storage temperature accelerates metabolic activities such as respiration, favoring the loss of vigor and accumulation of oxidative damage on the seeds (RODRIGUES et al. 2020, KRZYZANOWSKI et al. 2022). Inadequate seed storage negatively impacts plant establishment, resulting in an uneven distribution of plants in the field, leading to a decrease in overall crop productivity (BAGATELLI et al. 2019).

Seed treatment is a common practice in seed processing units, conducted before bagging or delivery of seeds to the producer. It can be done using various products such as fungicides, insecticides, nematicides, growth regulators, antibiotics, inoculants, dyes, among others, in order to improve the germination performance of seeds (CARVALHO & NAKAGAWA 2012). In addition to controlling seed-associated pathogens, seed treatment controls soil pests, storage fungi, and early root and leaf pathogens, and can ensure adequate stand, vigorous plants, and delay in the onset of epidemics (VAZQUEZ et al. 2014).

The effect of chemical treatment on seeds during storage is quite controversial, because depending on the combination and nature of the products used, there may be a reduction in the physiological quality of the seeds due to phytotoxicity. The response to treatment varies according to the cultivar and storage period (SALOMÃO et al. 2023).

Research on the effects of different storage temperatures on chemically treated corn seeds is necessary, as it is essential to identify ideal storage conditions that preserve seed quality. Thus, the objective of this work was to analyze the physiological quality of maize seeds treated with insecticides (Actellic 500 CE + K-obiol + Maxim X) and stored under three different temperatures over 90 days.

MATERIAL AND METHODS

The research was developed at the Laboratory of Plant Physiology, Seed Analysis and Technology and in a teaching area of the Federal Institute of Santa Catarina in the municipality of Canoinhas-SC. Maize seeds represented by three lots of the AL Bandeirante variety obtained from a rural producer in the region of Canoinhas were used. The climate of the municipality is classified as humid mesothermal, without a dry season, cool summers and frequent frosts in June, July and August. There is an average of 17.4 frosts a year, and an average rainfall of 1,473.3 mm (KÖPPEN & GEIGER 1928). The seeds were treated with insecticide based on Actellic 500 CE, K-obiol and Maxim X and sent to the laboratory for physiological analyses.

The experimental design was completely randomized in a split-plot scheme, in which the plots were the storage time and the subplots the temperatures. The maize seeds were stored in multiwall paper packages and BOD (Biochemical Oxygen Demand) chambers at temperatures of 10°C, 18°C and 26°C.

At 0, 30, 60 and 90 days after storage, the physiological quality of maize seeds was analyzed through the tests of moisture content, germination percentage, seedling emergence percentage in sand and accelerated aging test, while day 0 corresponded to the first evaluation before conservation. Seed samples were collected randomly for testing.

The moisture content (%U) of corn seeds was evaluated using a portable grain moisture meter (AL-102 Eco Agrologic) that holds approximately 500 grams of seeds, in four replications for each treatment. Then, the seed germination test was performed, distributing it evenly between two sheets of germitest paper, moistened with a volume of distilled water of 2.5 times the weight of the dry paper, with four replications of 50 seeds for each treatment. The paper rolls containing the seeds were kept in plastic bags at a temperature of approximately 23ºC. The percentage of the first germination count (%PCG) was estimated at four days of sowing and the percentage of germination (%G) at seven days of sowing (BRASIL, 2025).

The accelerated aging test of the maize seeds was done in an incubator (Lucadema) with the temperature previously set to 45ºC and the moisture content of approximately 90%. The seeds of each treatment were stored in containers, considering four replicates of 50 seeds, and were kept in the greenhouse for 72 h of exposure. Soon after, the samples were submitted to the germination test on germitest paper to evaluate the percentage of the first germination count (%PEN) at four days and the percentage of germination of aged seeds (%EN) at seven days (VIEIRA et al. 2005).

The emergence test of corn seedlings was done in a protected environment of 18 m^2, formed by a structure of concrete pillars with greenhouse plastic installed at 4 m, with the sides covered with shade. Sand was used as substrate, packed in plastic trays, in which sowing was done at a depth of approximately 2.0 cm from the substrate, with four replications of 25 seeds per tray, in each treatment. After sowing, watering and counting was done daily for up to seven days of sowing (BRASIL 2025). The percentage of the first emergence count (%PCE) was determined on the fourth day of sowing and the percentage of emergence (%E), emergence speed index (IVE), mean emergence time (TME) and average emergence speed (VME) were determined on the seventh day of sowing.

IVE was determined through the formula defined by MAGUIRE (1962):

IVE = ($N_1/D_1+N_2/D_2+... N_7/D_7$), where N corresponds to the number of seedlings emerged on a given day and D to the number of days after the implementation of the test.

TME and VME were estimated from the formulas proposed by Labouriau & Valadares (1976):

TME = ($N_1+N_2+...+ N_7/D_7$) and VME = 1/ TME, where N corresponds to the number of seedlings emerged on a given day and D corresponds to the total number of seedlings emerged on seven days.

The air temperature conditions and relative humidity were recorded by a datalogger (Tzone, TempU03) throughout the experimental period during the emergence test of corn seedlings (Figure 1). In general, the temperature ranged from 21ºC to 30ºC in the evaluations up to 90 days. On the day of sowing (time 0), the average temperature was 26.3ºC. At 30 days, the average temperature was 28ºC and in the evaluation at 60 days, the average temperature was 24ºC. At 90 days, the average temperature was 22ºC (Figure 1A). The average relative humidity was around 69% at time 0, 65% at time 30, 80% at time 60 and 84% at time 90 (Figure 1B). It was determined that the average temperatures and relative humidity were within the recommended range for corn emergence (EMBRAPA 2021).

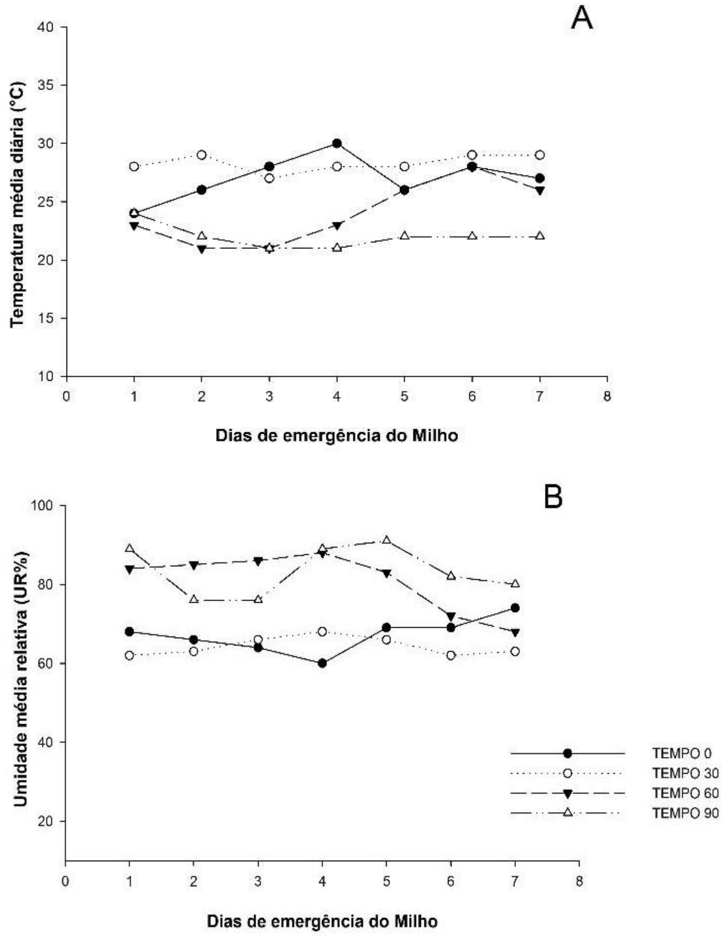

Figure 1. Daily averages of temperature (A) and relative humidity (B), recorded throughout the period of emergence evaluation of AL Bandeirante maize seedlings.

The data was submitted to analysis of variance and, when significant, the means were compared by the Tukey test at 5% probability, using the statistical software SISVAR (FERREIRA 2019).

RESULTS AND DISCUSSION

Analyzing the physiological quality of AL Bandeirante maize seeds stored at different temperatures, significant differences ($p<0.05$) in the interaction between storage time and temperature factors were identified from the analysis of variance for most of the variables studied, with the exception of the percentage of germination (%G) and the mean emergence time (TME) (Table 1).

The initial moisture content of the seeds before storage (day 0) was different between the temperature treatments, but it was determined that there was a reduction over time. Seeds stored at 26ºC showed higher %U than the other treatments from 30 days on, with an average of 12% at 30 and 60 days of storage and an average of 10% at 90 days. Regarding the temperature of 18ºC, it was determined that the humidity was on average 11% at 30 and 60 days, reducing at 90 days to an average of 9%. The lowest moisture content was observed in seeds preserved at 10ºC, with an average of 8% after 60 days of storage (Figure 2).

The difference in seed moisture content between the temperature treatments initially observed is probably due to evaporation variations and environmental conditions that affected seed moisture before storage. In general, the reduction in moisture content in seeds after storage possibly occurred due to their hygroscopic equilibrium with the conservation temperature.

Table 1. F values of analysis of variance for moisture content (%U), percentage of first germination count (%PCG), germination percentage (%G), percentage of first count after accelerated aging (%PEN), percentage of germination after accelerated aging (%EN), percentage of first emergence count (%PCE), emergence percentage (%E), emergence speed index (IVE), average emergence time (TME) and average emergence speed (VME) of AL Bandeirante maize seeds, stored at different times and temperatures.

		F values									
Source of variance	**GL**	**%U**	**%PCG**	**%G**	**%PEN**	**%EN**	**%PCE**	**%E**	**IVE**	**TME**	**VME**
Time	3	365,1*	583,9*	23,0*	83,9*	48,3*	74,2*	16,5*	58,5*	27,2*	25,5*
Temperature	2	6,3*	5,2*	1,8^{ns}	33,4*	40,9*	13,6*	3,4*	6,2*	4,7*	3,2*
Time x Temperature	6	68,8*	2,7*	1,1^{ns}	6,1*	4,7*	4,3*	7,7*	7,3*	1,3^{ns}	1,0*
CV plot (%)		4,3	6,0	3,7	27,7	17,7	20,5	13,4	12,0	6,4	6,5
CV subplot (%)		5,0	8,5	6,3	17,	13,2	21,2	11,5	11,5	6,4	7,1

Time: plot; Temperature: subplot; GL: degrees of freedom; *: significant at 5% by the Tukey test; ns: not significant; CV%: coefficient of variation.

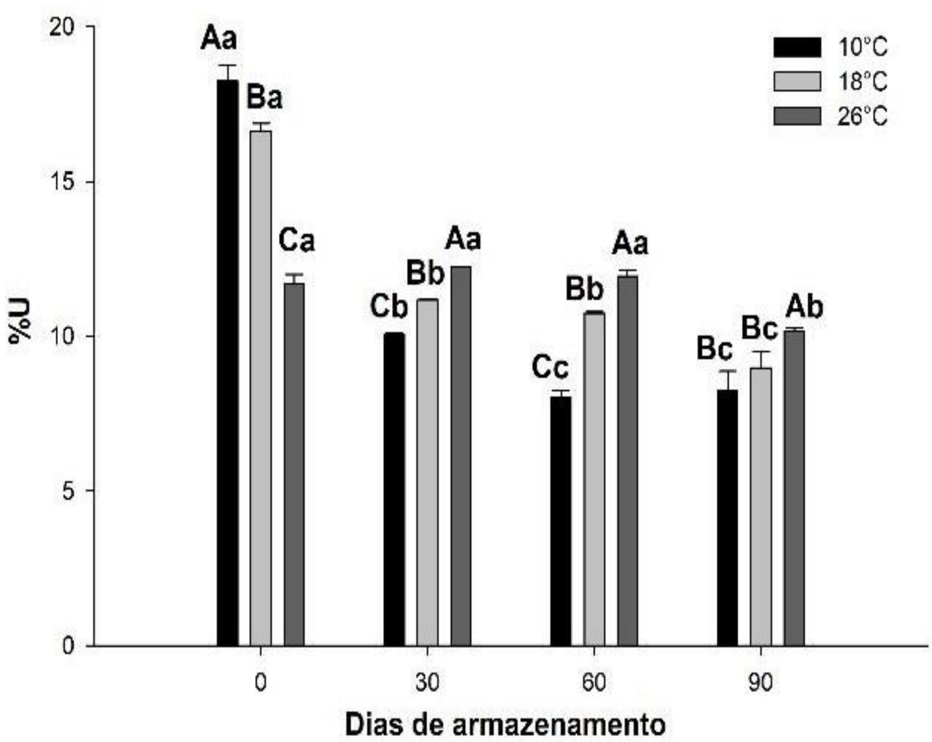

Figure 2. Moisture content (%U) of treated AL Bandeirante maize seeds, stored at different times and temperatures. Averages followed by the same letter do not differ from each other by Tukey test at 5% probability, uppercase letters compare temperatures at each time, and lowercase letters compare the isolated temperature over time. The bars indicate the standard error of the average of four repetitions.

According to CARVALHO et al. (2014), it is essential to consider the time and environmental conditions during seed storage. Seed conservation during storage can be attributed to the initial water contents and environmental conditions of the storage, with hydrolytic reactions stimulated when the seeds have a higher moisture content (OLIVEIRA et al. 2021).

In safe seed storage, an air temperature below 18°C and relative humidity between 50% and 60% are recommended. These conditions are key to preserving seed viability over time, minimizing metabolic activity and preventing spoilage caused by adverse conditions. Keeping the temperature low reduces the seed aging rate, while controlled moisture prevents premature germination and fungal development. Therefore, it is ensured that seeds remain in ideal conditions for future sowing, ensuring their quality and germination potential (MENEGHELLO 2014). During the storage of maize seeds at different temperatures, it was determined that all BOD chambers had air humidity around 50%, which is in accordance with the recommendation.

Analyzing the %PCG of maize seeds, it was verified that up to 30 days of storage there was no difference between thermal treatments. At 60 days, seeds stored at 18ºC and 26ºC showed an average of 89% germination, and those under 10 ºC had an average of 79.5%. However, with the advance of time, there was a reduction in %PCG, with a mean of 16% at 10ºC treatment and a mean of 31.7% at 18ºC and 26ºC (Figure 3A). The percentage of the first germination count is essential to assess the percentage of normal seedlings and determine the vigor of the seeds. In seed lots that have similar germination percentages, variations in germination speed are often observed, indicating that there may be differences in vigor between lots (CARVALHO & NAKAGAWA 2012).

Regarding %G, there was no difference between temperatures throughout the experimental period. However, seeds preserved at 10ºC and 26ºC showed differences over the days of storage, especially at 90 days, when it presented an average of 78.5% germination (Figure 3B). In this study, the germination capacity of corn seeds was on average 87% up to 90 days of storage, regardless of the treatment, therefore, the seeds used could be marketed in accordance with Brazilian legislation (BRASIL 2013).

The germination results corroborate MORAES et al. (2022) who verified the germination capacity of two corn hybrids (BM 950 PRO3 and BM 709 PRO2), in seeds treated with insecticides and stored at 10, 20 and 30°C, finding that each hybrid presented a different germination percentage under the thermal storage conditions, but remained within the minimum marketing standards for up to 360 days of conservation, regardless of the treatments.

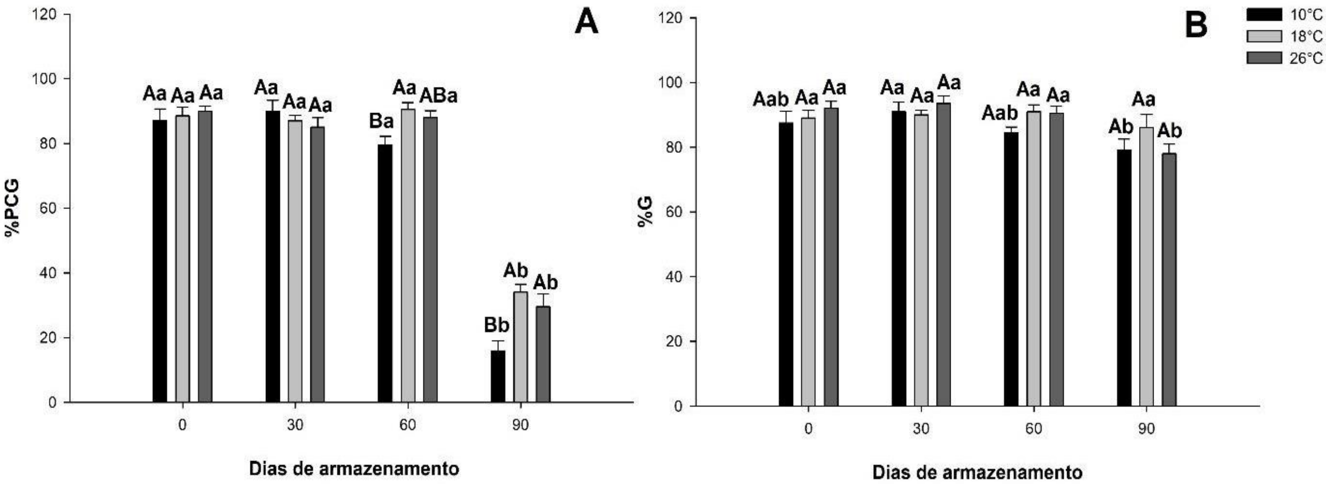

Figure 3. Percentage of first germination count (%PCG) (A) and germination percentage (%G) (B) of treated AL Bandeirante maize seeds, stored at different times and temperatures. Averages followed by the same letter do not differ from each other by Tukey test at 5% probability, uppercase letters compare temperatures at each time, and lowercase letters compare the isolated temperature over time. The bars indicate the standard error of the average of four repetitions.

After six months of storage in the laboratory, PEREIRA et al. (2005) found that the corn seeds of hybrids AG9010 and AG122 had germination above the established for commercialization, at 97%, finding that the treatment with phytosanitary products, insecticide and insecticide+fungicide, was responsible for the reduction in the percentage of these pathogens before and during storage. Even if the seeds have a high germination potential at the beginning of storage, if it is subjected to inadequate conditions to preserve their physiological quality, the germination rate can decrease over time, which can generate failures in the establishment of crops and reduce productivity.

Analyzing the germination capacity of maize seeds during 450 days of storage, HEBERLE et al. (2019) observed a decrease in germination rates of all lots after 90 days, regardless of environmental conditions, the authors emphasized that low temperatures and reduced relative humidity are crucial to preserve seed quality for an extended period, ensuring that they remain suitable for commercialization.

The germination test, despite being used in seed evaluation routine, is a test with limitations, as MARCOS FILHO (2015) points out, because it evaluates the germination power of seeds under ideal environmental conditions and that for the differentiation of lot quality it is necessary to use vigor tests. The same author also highlighted that germination test should not be replaced by vigor tests and that these should be complementary to detect differences that cannot be visualized in the germination test.

In the accelerated aging test, it was determined that there was no difference in %PEN between the thermal treatments at 0 days, however, at 30 days the seeds at temperatures of 26ºC showed a reduction in germination, with an average of 47%. Significant differences were observed with the advance of storage time, where at 90 days the average germination of the 10ºC treatment was 19%, the 18ºC treatment averaged 26% and the 26ºC treatment averaged 9.5% (Figure 4A).

It was found that seeds stored at 26ºC had the lowest average germination percentage after accelerated aging (%EN), with an average of 24% on day 0, 49.5% at 30 days, 33.5% at 60 days and 34% germination at 90 days. It can be observed that at 30 days of storage, there was the highest percentage of germination after accelerated aging, in seeds submitted to 10ºC and 18ºC, an average of 80%, with reductions during the conservation progress (Figure 4B).

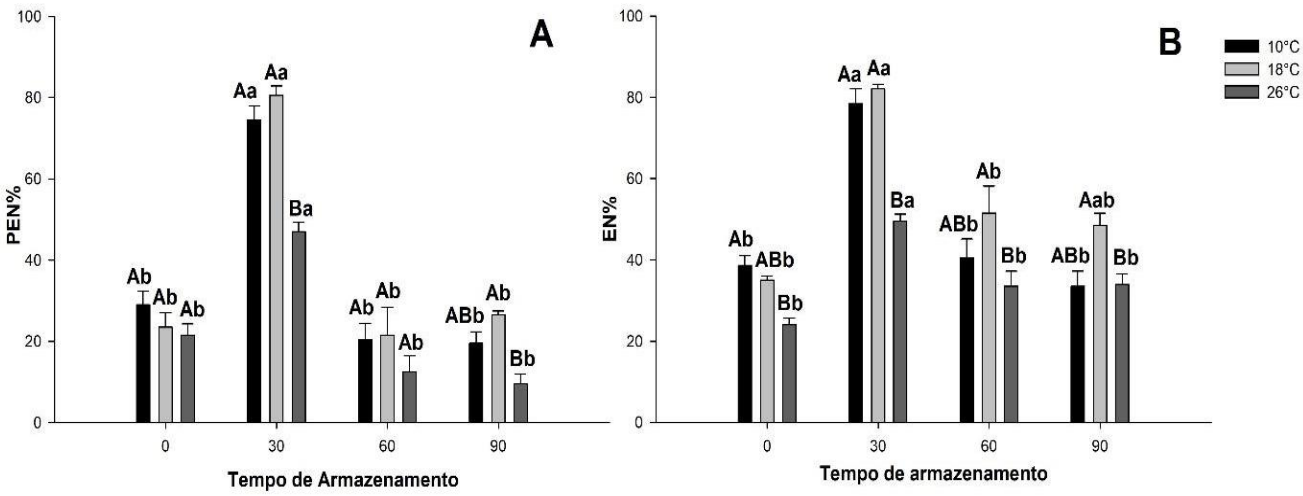

Figure 4. Percentage of first germination count (%PEN) (A) and percentage of germination (%EN) (B), both after the accelerated aging test of treated AL Bandeirante maize seeds, stored at different times and temperatures. Averages followed by the same letter do not differ from each other by Tukey test at 5% probability, uppercase letters compare temperatures at each time, and lowercase letters compare the isolated temperature over time. The bars indicate the standard error of the average of four repetitions.

FORTI et al. (2009) explain that variations in seed water content affect the rate of wetting and the intensity of deterioration, since seeds with lower water content have a higher water gradient, absorbing water faster than seeds with higher water content, consequently resulting in differences in seed deterioration. However, it was determined that possibly the germination variations after accelerated aging occurred mainly due to the influence of storage temperature, since the moisture content was between 8 and 10% at 90 days of conservation (Figure 2).

Accelerated aging is one of the methods used with excellent results to evaluate the physiological quality of seeds, since it is related to the probable deteriorating effect caused by the exposure of seeds to test conditions, high temperature and relative humidity, seeking to estimate the potential of seed lots (SPINOLA et al. 2000). The exposure of seeds to high levels of relative humidity and temperatures results in a period of stress similar to what occurs in natural aging, but at a higher rate.

The variation in the response of seeds to aging is what determines the effectiveness of the test. More robust seeds retain their ability to germinate and produce normal seedlings even after undergoing accelerated aging treatments, while those with lower vigor show a more pronounced drop in germination capacity and viability during this process (MARCOS FILHO 2015). The thermal treatments combined with the chemical treatment of corn seeds impaired the performance of the seeds after the application of the accelerated aging test, since there was a marked reduction in the percentage of germination, indicating the low vigor of the seeds (Figure 4).

Analyzing the emergence test of corn seedlings in sand, it was verified that there was no difference between the thermal treatments for %PCE in the evaluations up to 30 days. At 60 days, there was a reduction in %PCE in seeds at temperatures of 10ºC and 26ºC, where the average emergence was 6.5%, while at 18ºC the average emergence was 24% (Figure 5A).

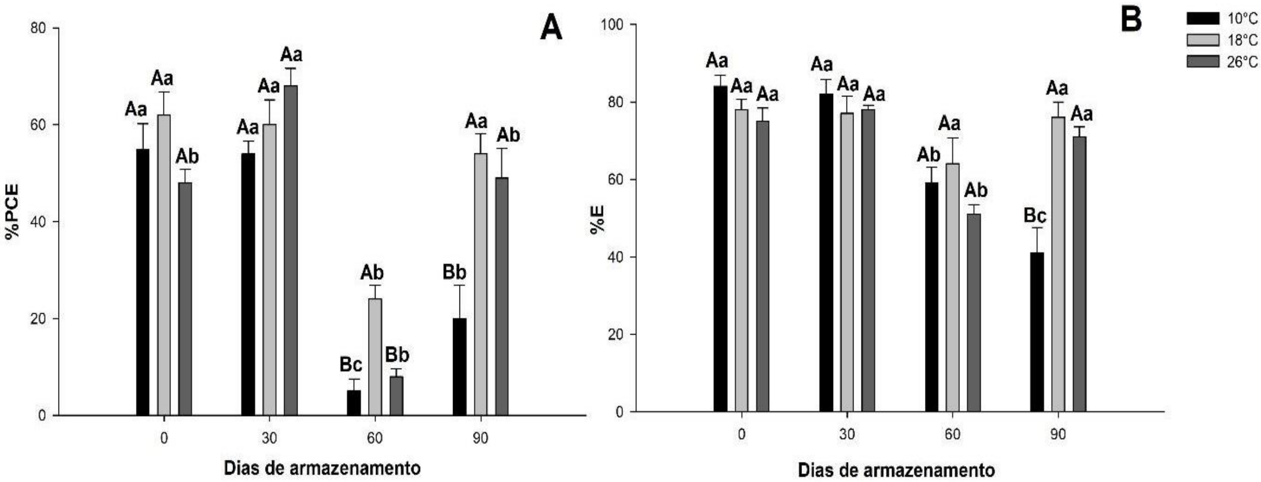

Figure 5. Percentage of first emergence count (%PCE) (A) and percentage of emergence (%E) (B) in sand of AL Bandeirante corn seedlings stored at different times and temperatures. Averages followed by the same letter do not differ from each other by Tukey test at 5% probability, uppercase letters compare temperatures at each time, and lowercase letters compare the isolated temperature over time. The bars indicate the standard error of the average of four repetitions.

As for %E, there was no difference between the conservation temperatures up to 60 days, with an overall average of 79% up to 30 days and an average of 58% at 60 days. However, at 90 days, a reduction in the percentage of seedling emergence from the thermal treatment at 10ºC was observed, with an average of 41% (Figure 5B), this reduction may be related to the loss of seed vigor with the advance of storage time. The emergence percentage refers to the proportion of seeds that germinate and emerge above the soil surface or substrate in relation to the total seeds sown.

ROSA et al. (2012) highlights that the physiological quality of seeds after chemical treatment and storage is strongly linked to the genetic material used in the study. This means that different cultivars and hybrids respond differently to treatments, making it essential to determine the specific treatment and storage conditions suitable for each type of genetic material.

Several authors state that the quality of stored hybrid maize seeds treated with insecticides is influenced not only by the chemicals used in their treatment but is also dependent on the genotype and environmental conditions of storage (BITTENCOURT et al. 2018).

Thermal treatments did not influence the IVE up to 30 days. At 60 days of storage, there was a decrease in IVE, where the average for temperatures of 10ºC and 26ºC was around 3.0% and the treatment at 18ºC averaged 3.5%. At 90 days, the mean IVE in the treatment at 10ºC was 2.1% and 4.0% for the temperatures of 18ºC and 26ºC (Figure 6A). The higher the value of IVE, the greater the capacity of the seeds to express their germination potential, and it changes depending on the variables that are analyzed (MARCOS FILHO 2015).

CARVALHO & NAKAGAWA (2012) show that any delay or decrease in the speed of the germination process increases the susceptibility of seeds to attacks by microorganisms present in the soil, reducing seedling emergence and compromising the final stand of the crop.

As for TME, there was no difference between the thermal treatments, but there was a significant difference in the analysis of temperatures in isolation throughout the storage period. At 60 and 90 days, seeds preserved at 10ºC, 18ºC and 26ºC showed a TME of approximately 5.0 days (Figure 6B). TME is an important criterion in the selection and development of new seed varieties, helping to identify those with best performance under varying conditions. It is calculated from observations from the time the seeds are planted to the time a significant amount of them emerges.

Analyzing VME at 0 days, a mean of 0.23 days^{-1} was verified, and in the last evaluation at 90 days, the same parameter obtained a mean of 0.21 days^{-1} (Figure 6C). VME is directly linked to the vigor of seeds, the faster the seed germinates, the greater its vigor. The average speed of seed emergence is an important parameter to evaluate the performance and health of seeds during the germination process and initial growth of plants. This calculation allows for the determination of the average speed necessary for most seeds to begin to germinate and emerge from the soil and the lower the average emergence speed value, the greater the physiological potential of the seeds.

Considering Figure 6, it was determined that the thermal treatments did not influence TME and VME variables during the emergence test in sand, demonstrating that these variables were not efficient to contrast the treatments, especially for 60 days of storage, in which the greatest variations were observed in the emergence test (Figure 5).

The unevenness of emergence speed can affect the vegetative development of corn, as the seedlings that emerge first shade those that emerge later and, consequently, impairs their development (HENRICHSEN 2021). TIMÓTEO & MARCOS-FILHO (2013), evaluating the performance of different maize genotypes, observed that as the storage time extends, there is an increase in the deterioration of the physiological quality of the seeds.

Storage conditions, especially temperature, play a crucial role in preserving seed quality attributes. Lower temperatures tend to prolong seed viability, while higher temperatures accelerate spoilage. Considering seeds treated with insecticides, deterioration can be even faster. Strict control of storage conditions and physiological quality of maize seeds are essential to ensure the use of viable and vigorous seeds in the field.

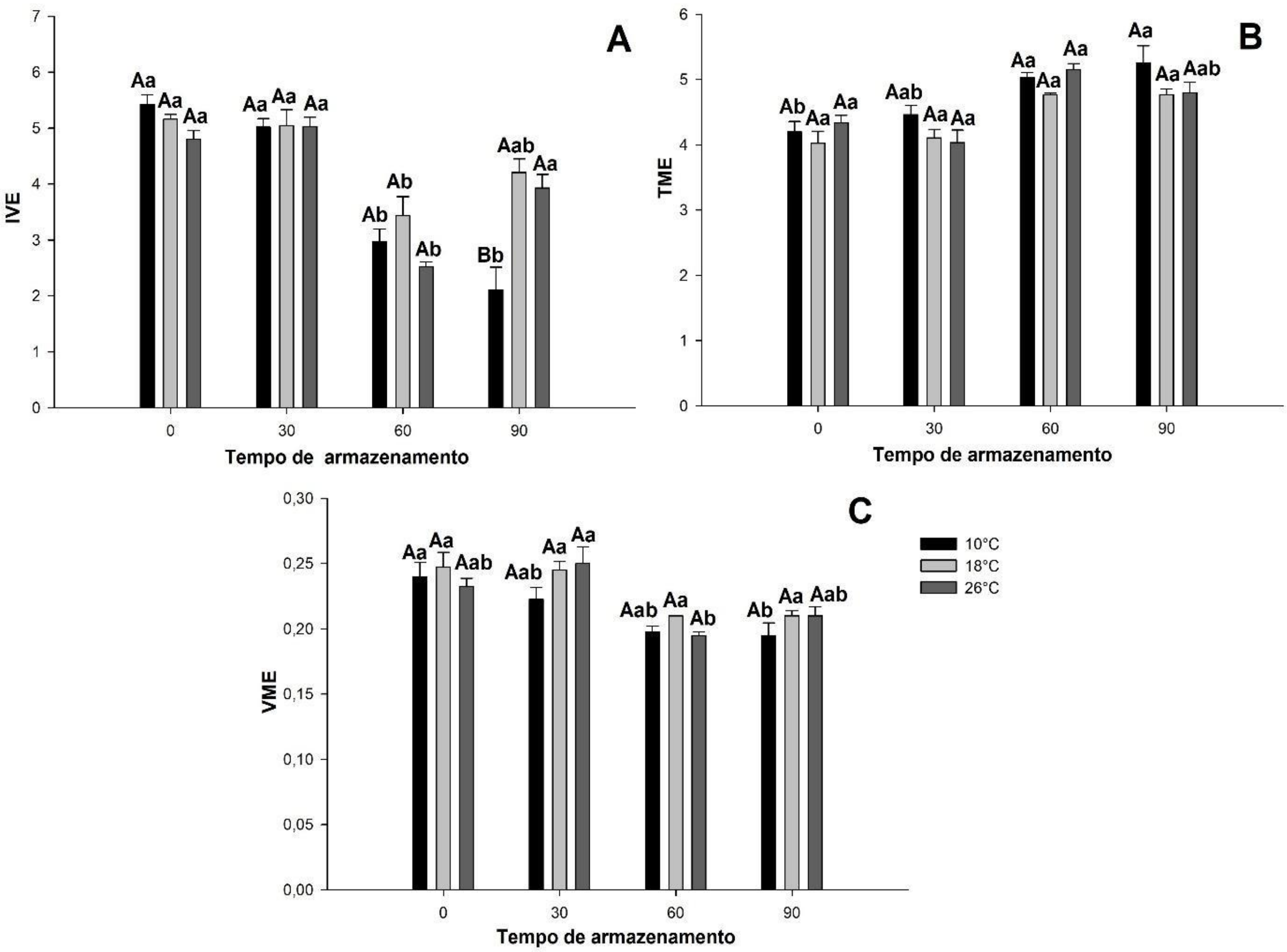

Figure 6. Emergence speed index (IVE) (A), average emergence time (TME) (B)[A1.1] and average emergence speed (VME) (C) of AL Bandeirante maize seedlings, stored at different times and temperatures. Averages followed by the same letter do not differ from each other by Tukey test at 5% probability, uppercase letters compare temperatures at each time, and lowercase letters compare the isolated temperature over time. The bars indicate the standard error of the average of four repetitions.

CONCLUSION

The moisture content of AL Bandeirante corn seeds treated with insecticide decreases over storage time, with significant reductions in temperatures of 10ºC and 18ºC, indicating that lower temperatures are favorable for conservation.

The percentage of the first germination count is reduced at 90 days of storage; however, the germination percentage of corn seeds is maintained above 80%, regardless of storage temperatures of 10ºC, 18ºC and 26ºC.

The accelerated aging test shows loss of vigor of treated corn seeds after 30 days of storage. The percentage of the first emergency count was also reduced from this period.

Although there were no differences between thermal treatments on the percentage of emergence at 60 days of conservation, there was a reduction of approximately 20% in seedling emergence in relation to 30 days of conservation.

The emergence speed index is affected after 30 days of storage, but the average emergence time remains constant in seeds stored at 10ºC, 18ºC and 26ºC up to 90 days. The average emergence speed remains stable at different temperatures, from 60 days of conservation.

Although the percentage of germination of treated corn seeds is not altered in heat treatments up to 90 days of storage, the vigor of the seeds is compromised. Based on the results, it is suggested to store corn seeds treated with insecticide for up to 30 days, aiming at rapid and uniform germination, with normal seedling formation.

AUTHOR CONTRIBUTIONS

Conceptualization, methodology and formal analysis, SANTOS, AL; SENEN, SC and PEREIRA LFM; software and validation, SANTOS, AL; SENEN, SC and PEREIRA LFM; investigation, SANTOS, AL; resources and data curation, PEREIRA LFM; writing - preparation of the original draft, SANTOS, AL and PEREIRA LFM; writing - review and editing, SENEN, SC and PEREIRA LFM; visualization, SANTOS, AL; SENEN, SC and PEREIRA LFM; supervision, PEREIRA LFM; project management, SANTOS, AL and PEREIRA LFM; fundraising, PEREIRA LFM. All authors have read and agreed with the published version of the manuscript.

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STATEMENT OF THE INSTITUTIONAL REVIEW BOARD

Not applicable to studies that do not involve humans or animals.

INFORMED CONSENT STATEMENT

Not applicable because this study did not involve humans.

DATA AVAILABILITY STATEMENT

The data can be made available upon request.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest related to this publication.

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