CAPÍTULO 12

Physiological Quality Of Wheat Seeds As A Function Of Storage Time

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ABSTRACT: Wheat is one of the main winter cereal crops produced in Brazil, with great socio-economic importance to meet both domestic and global demand. It is also an important crop in essential crop rotation systems under conservation tillage systems. However, due to the need to store seeds for future sowing, their quality may decline over time, causing losses to producers. Thus, this study aimed to evaluate the quality of wheat seeds subjected to different storage periods of 24 and 12 months. The evaluation standards followed the RAS (Rules for Seed Analysis) and relevant scientific literature. The parameters evaluated were water content (WC), germination (G%), first count (FC), emergence speed index (ESI), field emergence (FE), electrical conductivity (EC), tetrazolium test (TZ), and accelerated aging (AA). For the analysis of ESI and EC, a randomized block design (RBD) was used, while for the other analyses a completely randomized design (CRD) was adopted, comprising six treatments with four replications. A reduction in physiological potential was observed with increasing storage time of wheat seeds. In addition, different responses were noted among genotypes regardless of the storage period, with one genotype showing a higher rate of deterioration.

KEYWORDS: Deterioration. Accelerated aging. Vigor.

INTRODUCTION

Wheat (Triticum aestivum) is the main winter crop in Southern Brazil and has recently been expanding into the Central-West region. Wheat production has notable economic relevance in the Brazilian market, representing an important source of income for farmers during the winter season and contributing significantly to the sustainable development of agribusiness. It is the second most produced cereal crop worldwide, with substantial importance in the global agricultural economy (MAPA, 2015). In addition, wheat is the main species used in crop rotation systems.

Historical data indicate that in the 2005/06 growing season, the Brazilian average yield was 2,063 kg ha^{-1}, while in the 2013/14 season it reached an average of 2,165 kg ha^{-1}, representing an increase of 4.71% per hectare (CONAB, 2015b). Despite this progress, continuous efforts are made to increase yield, and for this purpose it is essential to produce and use seeds with high physiological quality, since the entire production process begins with the seed (MERTZ et al., 2012). Furthermore, seed costs account for approximately 15.3% of the variable costs and 9.7% of the total production cost (CONAB, 2015a).

Seeds are an input that influences plant development from sowing to harvest, and their effects, whether positive or negative, persist from the beginning to the end of the crop cycle. As the only biological input in agriculture, seeds require high investments, strict control, and a high standard of quality. Therefore, breeding and seed multiplication companies annually invest millions to modernize laboratories, processing procedures, and storage conditions in order to maintain seed quality and ensure the profitability expected by farmers.

Among the factors that require attention to fully exploit wheat yield potential, the use of high-quality seeds stands out, both in terms of genetic and physiological components (MARCOS FILHO, 2005). To obtain seeds with high quality, it is necessary to continuously monitor the fundamental processes of the production cycle, from sowing to commercialization, especially the storage process, which is essential to prevent irreversible losses if not properly managed.

Several factors may interfere with the loss of seed viability during storage, such as damage to the genome and to membrane and enzyme systems. Marcos Filho (2005) states that, in general, the lower the temperature and relative humidity in the storage environment, the greater the seed longevity due to reduced metabolic activity, thereby maintaining macromolecular stability and providing greater security to producers by ensuring better stand uniformity, productivity, and consequently profitability.

Seed longevity, in addition to varying according to genotype, largely depends on seed moisture content and storage environmental conditions, directly influencing seed quality (MARCOS FILHO, 2005). For this reason, storage is a crucial stage in seed production programs, since harvest time does not coincide with the ideal sowing time (PLAZAS, 2003). Therefore, many farmers use seeds stored for long periods. Under adequate conditions, seeds may be stored without deterioration; however, under improper conditions, they can deteriorate easily, altering their physiological quality, which is an irreversible factor that reduces yield potential.

Thus, the evaluation of seed physiological quality is essential for seed-producing companies and institutions linked to the sector, as it allows the determination of the real potential of seed lots and, through analyses, the adoption of management practices that ensure an acceptable level of seed performance, thereby optimizing the production process (LIMA, 2006).

Once germination begins, seedling development becomes controlled by the genome and its interaction with the environment. Therefore, non-uniform and low-vigor seedlings are likely the result of damage to the genome or vital seed structures during storage (MARCOS FILHO, 2005). Evaluating seed physiological potential allows consistent identification of seed lots with greater likelihood of successful field establishment under wide environmental variability. In this context, laboratory results correspond to field performance when pre- and post-sowing climatic conditions are favorable for emergence and plant development (MARCOS FILHO, 2013).

In view of the above, the objective of the present study was to evaluate the physiological potential of seeds from different wheat genotypes in response to storage periods.

MATERIAL AND METHODS

The experiment was conducted at the Seed Laboratory of the Federal University of Santa Maria, Frederico Westphalen Campus, during the second semester of 2015. Three cultivars were used, with four replications of seed lots stored for two periods (24 and 12 months). The lots presented similar initial quality and were stored under the same environmental and location conditions. A randomized block design in a factorial scheme was adopted for the analysis of emergence speed index (ESI) and first count (FC). For the other laboratory analyses, a completely randomized design (CRD) was used.

The tests and determinations used to characterize the seed lots were based on the methodology described in the Rules for Seed Analysis (RAS) (BRASIL, 2009) and are described below:

1. Water Content (WC): Determined using a moisture meter (Gehaka, model BK 6600). Four samples per treatment were used, each with a uniform weight of 143 g.
2. Germination Test (G): A total of 400 seeds per treatment were used, subdivided into four replications. The seeds were placed between three sheets of Germitest paper, moistened with water equivalent to 2.5 times the weight of the dry paper, and incubated in a BOD-type chamber at a constant temperature of 20°C with a 12-hour photoperiod. Final germination percentage was determined by counting normal seedlings, as well as abnormal seedlings and dead seeds, eight days after the beginning of the test.
3. First Count of Germination (FC): Conducted together with the germination test, by counting the percentage of normal seedlings on the fourth day after sowing (BRASIL, 2009).
4. Emergence Speed Index (ESI): Performed according to the methodology proposed by Popinigis (1985). Two hundred seeds per treatment were sown in seedbeds, subdivided into four replications, arranged in rows spaced 17 cm apart and distributed in randomized blocks. Daily counts of emerged seedlings, with well-developed shoots, were recorded until 21 days after sowing, when emergence stabilized. The index was calculated using the formula:

$ESI = E_1/N_1 + E_2/N_2 + ... + E\ /N$

where:

ESI = emergence speed index;

E_1, E_2, …, E = number of normal seedlings counted at the first, second, and final evaluations;

N_1, N_2, …, N = number of days from sowing to the first, second, and final counts.

5. Field Emergence (FE): Determined together with the emergence speed index by counting the number of established seedlings at 21 days after sowing.
6. Electrical Conductivity (EC): The test was conducted with four replications of 50 seeds per treatment, according to the methodology described by Lima et al. (2006). Seeds were weighed and placed in plastic cups containing 75 mL of distilled water. The cups were maintained in a BOD germinator at 25°C

for 18 hours. After this period, electrical conductivity was measured using a portable conductivity meter, and the results were expressed in µS cm^{-1} g^{-1}.

7. Tetrazolium Test (TZ): Two hundred seeds per treatment were used, subdivided into four replications. Seeds were pre-moistened between paper towels for 18 hours at 20°C in a BOD chamber. Subsequently, they were immersed in a 0.5% tetrazolium solution for 2 hours at 40°C, allowing staining of both seed halves (BRASIL, 2009). Evaluation followed the classification proposed by Carvalho et al. (2012), who established four classes for vigor determination: Class 1 – Viable and vigorous; Class 2 – Viable and non-vigorous; Class 3 – Non-viable; Class 4 – Dead.

8. Accelerated Aging (AA): For this test, 400 seeds per treatment were used, subdivided into four replications. Forty milliliters of water were added to the bottom of plastic "gerbox" boxes. Seeds were distributed in a single layer over a metal screen fixed inside the boxes. The boxes were sealed to obtain approximately 95–100% relative humidity inside and maintained at 43°C for 48 hours in a BOD incubator. This methodology was chosen based on the satisfactory results obtained by Ohlson (2010). After the aging period, the seeds were subjected to the germination test according to RAS methodology (BRASIL, 2009). Evaluation was performed four days after sowing, and results were expressed as the percentage of normal seedlings.

The data were subjected to analysis of variance (ANOVA) using Sisvar software version 5.3 (FERREIRA, 2008). Means were compared using Tukey's test ($p < 0.05$). Graphs were prepared using SigmaPlot 12.5 software (SYSTAT SOFTWARE, 2013).

RESULTS AND DISCUSSION

Based on the analysis of seed moisture content (Table 1), it was observed that no significant differences were detected among cultivars within either storage period. However, when comparing storage periods, a statistical difference was found only for cultivar 1, which exhibited a higher moisture content after 12 months of storage.

It is important to emphasize that the grain storage process is critically important due to the occurrence of a series of biochemical alterations that may lead to seed deterioration if seeds are not maintained under appropriate conservation conditions (SANTOS et al., 2005).

Cultivars	Initial Moisture Content (%)		Final Moisture Content (%)	
	Storage Period (months)			
	24	12	24	12
Cultivar 1	13,20	14,00	14,30 Ab	14,67 Aa
Cultivar 2	13,00	13,10	14,32 Aa	14,47 Aa
Cultivar 3	13,10	13,00	14,65 Aa	14,55 Aa
C.V. (%)	4,26	3,15	2,54	1,64

*Means followed by different lowercase letters within rows and uppercase letters within columns differ significantly according to Tukey's test at the 5% probability level.

Table 1. Seed moisture content (%) at the beginning and after storage for different wheat cultivars subjected to two storage periods (24 and 12 months).

Seed physiological activity is dependent on moisture content, which directly influences respiratory activity according to Popinigis (1985). In this context, França-Neto et al. (2007) recommend that wheat seed moisture content during storage in Rio Grande do Sul be maintained between 13% and 13.5% in order to preserve physiological potential throughout storage. Furthermore, Plazas et al. (2003) reported a reduction in wheat seed germination associated with accelerated deterioration caused by elevated seed moisture content.

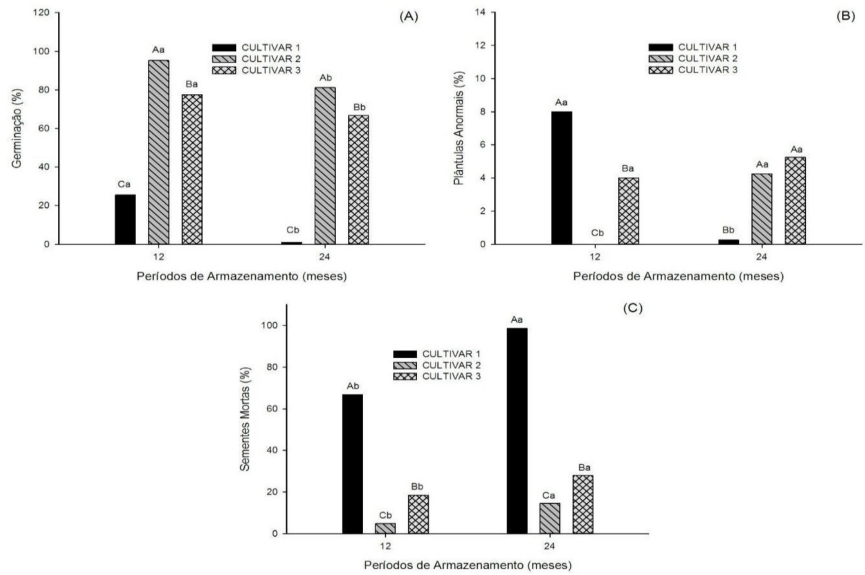
Thus, it can be inferred that during storage the relative humidity within the storage environment increased, consequently raising seed moisture content, accelerating respiration, and promoting the deterioration process. However, it is evident that this factor influenced both storage treatments to a similar magnitude, since moisture content did not differ significantly between periods and cultivars, with the exception of cultivar 1.

It was observed that seed moisture increased from the initial 13% to 14.3% and 14.7%, as shown in Table 1, thereby affecting storage potential. According to Henning et al. (2005), when seed moisture content reaches or exceeds 13.5%, deterioration may intensify. This variation in moisture content is related to the hygroscopic nature of seeds, meaning that their moisture content remains in equilibrium with the relative humidity of the air, fluctuating according to changes in environmental relative humidity during storage. Together with temperature, this factor constitutes one of the primary determinants of storage longevity (MARCOS FILHO, 2005). Under such conditions, damage to the seed coat may frequently occur, as increased metabolic activity accelerates deterioration, ultimately resulting in a reduction in physiological quality, as reported by Plazas et al. (2003).

According to Santos et al. (2005), as seed hydration increases due to elevated moisture content, the reduction in germination becomes more pronounced, leading to greater seed damage. Additionally, high moisture levels may favor fungal development, altering the microenvironment associated with the seed. As a consequence, seed tissues are progressively degraded, accelerating deterioration. Moreover, these fungi may produce mycotoxins that inhibit protein and nucleic acid synthesis, thereby further intensifying the deterioration of stored seeds (MARCOS FILHO, 2005).

Seeds with moisture content between 13% and 14% are commonly observed due to the large scale of storage facilities designed to accommodate substantial product volumes, which makes strict humidity control difficult. Consequently, it is challenging to maintain moisture at very low recommended levels. This situation is further influenced by the subtropical climate of southern Brazil, characterized by high relative humidity, regular rainfall distribution, and mild temperatures throughout the year.

Figure 1 presents the results for Germination percentage, Abnormal Seedlings, and Dead Seeds. Significant differences were observed among cultivars and storage periods for all analyzed variables. Regarding Germination (Figure 1A), cultivar 2 exhibited the best performance, differing statistically from the others. Concomitantly, this cultivar showed the lowest proportion of dead seeds, indicating greater physiological potential compared to cultivars 1 and 3. A direct and inverse relationship between germination and dead seed proportion can be observed (Figure 1C), in which cultivars with higher proportions of dead seeds exhibited reduced germination, and vice versa.



*Means followed by different lowercase letters between storage periods and uppercase letters among cultivars differ significantly according to Tukey's test at the 5% probability level.

Figure 1. Germination percentage, abnormal seedlings, and dead seeds of three wheat cultivars evaluated after 12 and 24 months of storage.

The influence of storage period on seed physiological potential is evident, as the 12-month storage period resulted in a higher number of germinated seeds compared to 24 months, differing significantly across all tested cultivars. A similar pattern was observed for dead seeds, with the 12-month period presenting a lower proportion compared to 24 months. This effect may be explained by the fact that seeds subjected to longer storage periods experience greater carbohydrate consumption and a reduction in reserve compounds due to increased enzymatic activity, leading to a decline in physiological potential (POPINIGIS, 1985). These findings are consistent with those reported by Abreu et al. (2013), who observed a reduction in sunflower seed germination percentage over storage time.

Table 2 presents the values for first count (FC), emergence speed index (ESI), field emergence (FE), and electrical conductivity (EC) for the storage periods and different cultivars. The analysis of the first count indicates that cultivar 2 outperformed the others, differing statistically from cultivar 1, which exhibited the lowest values, and from cultivar 3, which showed intermediate performance. Alvarenga et al. (1984) considered this index adequate for evaluating vigor in watermelon seeds, and similar conclusions were reported by Bhering et al. (2000) when differentiating vigor among cucumber seed lots. However, Bhering et al. (2000) emphasized that this test may not detect subtle differences in seed vigor.

Cultivars	PC (%)		IVE (%)	
	Storage Period (months)			
	24	12	24	12
Cultivar 1	0,75 Cb	17,50 Ca	0,1643Ba	0,1639 Ba
Cultivar 2	76,50 Ab	93,75 Aa	3,7115 Aa	4,4667 Aa
Cultivar 3	61,61 Bb	75,00 Ba	3,3905 Aa	3,7982 Aa
C.V. (%)	6,52		30,86	
	EC (%)		CE (µS/cm/g)	
Cultivars	Storage Period (months)			
	24	12	24	12
Cultivar 1	3,00 Ba	3,00 Ba	38,8551 Aa	28,4740 Ab
Cultivar 2	54,00 Aa	66,00 Aa	17,4290 Ca	13,7518 Ba
Cultivar 3	54,00 Aa	58,00 Aa	24,3275 Ba	28,2979 Aa
C.V. (%)	17,06		14,38	

*Means followed by different lowercase letters within rows and uppercase letters within columns differ significantly according to Tukey's test at the 5% probability level.

Table 2. First Count (FC), Emergence Speed Index (ESI), Field Emergence (FE), and Electrical Conductivity (EC) values of wheat seed cultivars after two storage periods. Frederico Westphalen – RS, 2015.

A significant difference was observed for First Count (Table 2) when comparing storage periods, with the 12-month period presenting superior results compared to 24 months for all analyzed cultivars. A similar trend was observed in the final germination analysis (Table 1). This can be explained by the fact that seeds stored for longer periods exhibit increased enzymatic activity, leading to greater consumption of starch reserves within the grain, which are utilized for energy production through respiration as well as for the synthesis of complex molecules (POPINIGIS, 1985). This phenomenon is evident in the present study, as seeds subjected to longer storage periods generally showed lower physiological quality for germination processes.

Regarding the Emergence Speed Index (ESI), cultivars 2 and 3 exhibited the highest indices across storage periods, demonstrating greater vigor of these seed lots. Although they did not differ statistically from each other, both differed from cultivar

1, which showed inferior results. When comparing storage periods, no significant differences in ESI were observed for any of the evaluated cultivars. These findings differ from those reported by Pereira et al. (2013), who, working with physic nut (Jatropha curcas L.) seeds, observed a significant reduction in seedling emergence with increasing storage duration.

For the field emergence parameter, significant differences were detected among the cultivars evaluated. Cultivar 1 exhibited the lowest performance compared to cultivars 2 and 3, which did not differ statistically from each other. Although the comparison between storage periods did not reveal statistical differences for any cultivar, a numerical reduction in emergence was observed with increasing storage time. According to Marques et al. (2014), genotype may influence this parameter, as some cultivars do not exhibit significant reductions in field emergence with prolonged storage.

Finally, regarding electrical conductivity values, significant differences were observed among cultivars after 24 months of storage, with cultivar 1 presenting the highest values, followed by cultivar 3 and then cultivar 2. After 12 months of storage, cultivars 1 and 3 differed statistically from cultivar 2, but not from each other. No significant differences between storage periods were detected for cultivars 2 and 3; however, for cultivar 1, higher conductivity values were observed after 24 months compared to 12 months, indicating increased solute leakage with prolonged storage time and consequently lower seed vigor. This suggests a genetic influence on this parameter, as variations in electrical conductivity among genotypes were also reported by Vieira et al. (2002).

This difference may also be explained based on the findings of Panobianco et al. (1999) and Alvarez et al. (1997), who reported that electrical conductivity values are influenced by the lignin content of the seed coat. Therefore, cultivar 1 may possess a lower lignin content in the seed coat, making it more susceptible to membrane deterioration over storage time. Furthermore, since the moisture content of cultivar 1 seeds stored for 12 months was statistically higher than that observed for 24 months, this increase likely influenced the results by reducing electrical conductivity values, as reported by Vieira et al. (2002).

Overall, it can be concluded that, regardless of storage duration, cultivar 2 exhibited higher vigor levels, as evidenced by lower electrical conductivity values resulting from reduced solute leakage, indicating greater membrane integrity and consequently lower deterioration.

Table 3 presents the mean vigor values for each class evaluated by the tetrazolium test, according to the methodology described by Carvalho et al. (2012). As the class number increases, seed physiological potential decreases, reflected by lower percentages of vigorous seeds and higher proportions of dead and non-viable seeds. Vigor is extremely important for seed performance; according to Khah et al. (1989), low-vigor seeds negatively affect seedling growth, whereas high vigor levels contribute to greater grain yield due to the initial advantage conferred to seedlings.

Cultivars	TZ (Class 1) (%)		TZ (Class 2) (%)	
	Storage Period (months)			
	24	12	24	12
Cultivar 1	0,25 Ba	0,50 Ca	16,75 Aa	2,50 Bb
Cultivar 2	9,00 Ab	40,00 Aa	13,75 Aa	5,25 ABb
Cultivar 3	11,75 Ab	36,00 Ba	13,75 Aa	10,75 Aa
C.V. (%)	11,78		32,03	
	TZ (Class 3) (%)		TZ (Class 4) (%)	
Cultivars	Storage Period (months)			
	24	12	24	12
Cultivar 1	5,75 Bb	18,25 Aa	42,00 Aa	14,50 Ab
Cultivar 2	17,50 Aa	3,50 Bb	9,75 Ba	1,25 Bb
Cultivar 3	15,25 Aa	2,50 Bb	9,25 Ba	0,75 Bb
C.V. (%)	29,33		19,64	

*Means followed by different lowercase letters within rows and uppercase letters within columns differ significantly according to Tukey's test at the 5% probability level.

Table 3. Tetrazolium test results for wheat seed cultivars after two storage periods. Frederico Westphalen – RS, 2015.

When comparing cultivars within Class 1 for each storage period, it can be observed that at 24 months cultivars 2 and 3 differed statistically from cultivar 1, but not from each other. Cultivar 1 exhibited extremely low levels of viable and vigorous seeds, reflecting a greater degree of deterioration. According to França Neto et al. (1998), several factors may influence the deterioration process, including drying, processing, water stress, and frost, all of which may cause severe damage to vital seed structures. For the 12-month period, clear differences among cultivars were observed, with cultivar 2 presenting the highest values of viable and vigorous seeds, followed by cultivar 3 and, lastly, cultivar 1.

When comparing the two storage periods, differences in vigor levels become evident. Cultivars 2 and 3 showed markedly higher values at 12 months compared to 24 months. Although cultivar 1 did not show a statistically significant difference between storage periods, a clear numerical reduction in viable and vigorous seeds was observed over time. This finding supports the statement by Popinigis (1985), who emphasized that a seed will never exhibit superior physiological quality tomorrow compared to today; rather, its viability will decline as a consequence of the deterioration process.

In Class 2, no significant differences among cultivars were observed at 24 months. However, at 12 months, cultivar 1 differed from cultivar 3 but not from cultivar 2. Cultivars 1 and 2 showed significant differences between storage periods, presenting higher values at 24 months, indicating greater vigor loss over storage time. Although cultivar 3 did not show statistical differences between periods, it exhibited a similar response pattern to the other cultivars, albeit with lower magnitude.

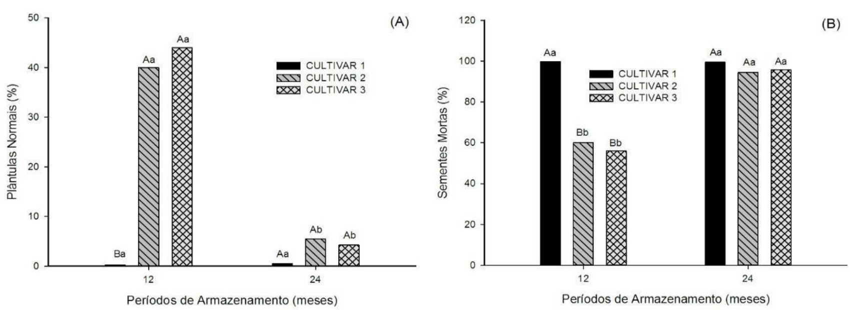
In Class 3, cultivars 2 and 3 displayed similar behavior across both storage periods, differing considerably from cultivar 1. All cultivars showed differences between storage periods, with cultivars 2 and 3 exhibiting an increase in the proportion of non-viable seeds over time. In contrast, cultivar 1 presented a higher percentage of non-viable seeds at 12 months.

In Class 4, a clear difference was observed between cultivar 1 and cultivars 2 and 3 in both storage periods, with cultivar 1 showing significantly higher percentages of dead seeds. When contrasting storage periods, the difference becomes even more pronounced, with higher percentages of dead seeds at 24 months, evidencing irreversible seed deterioration and severe embryo damage leading to seed death. These results corroborate Delouche (2002), who stated that the deterioration process is characterized by seed aging and death, with vigor being the primary component of seed quality affected by deterioration. The higher incidence of dead seeds in cultivar 1 is likely associated with lower seed coat resistance to fungal and insect attack, which considerably accelerates deterioration. According to Freitas et al. (2000), increasing storage duration raises fungal incidence, resulting in a linear decline in seed viability and vigor.

Overall, the results reveal that as storage time progresses, seeds experience a marked reduction in vigor and longevity. According to França Neto et al. (2001), reduced vigor diminishes the potential for germination, emergence, and successful establishment of normal plants under varying environmental conditions. Supporting these findings, Tozzo and Peske (2008) also reported that soybean seed vigor and viability decrease over storage time.

Regarding the percentage of Normal Seedlings obtained after accelerated aging (Figure 2A), no significant differences among cultivars were observed at 24 months of storage, although lower and higher values were numerically observed for cultivar 1 and cultivar 2, respectively. At 12 months, cultivars 2 and 3 did not differ significantly from each other but differed from cultivar 1, presenting higher percentages of normal seedlings. Cultivar 1 consistently exhibited low percentages of normal seedlings and consequently higher values of dead seeds (Figure 2B), with no statistical difference between storage periods.

This variation among cultivars is likely attributable to genotype influence on factors related to seed deterioration, such as greater susceptibility to microorganism attack, as described by Marcos Filho (2005). Additionally, Basajavarajappa et al. (1991) reported that accelerated aging reduced total carbohydrate reserves in maize seeds, decreasing sugar and protein contents, which contributed to membrane deterioration and subsequent seed quality decline.



*Means followed by different lowercase letters between storage periods and uppercase letters among cultivars differ significantly according to Tukey's test at the 5% probability level.

Figure 2. Percentage of normal seedlings and dead seeds in three wheat cultivars evaluated after 12 and 24 months of storage, following the accelerated aging test.

It is evident that the conditions of high temperature and humidity underlying the accelerated aging test exerted a considerable influence across storage periods, promoting irreversible seed deterioration, reducing the percentage of normal seedlings, and consequently increasing the proportion of dead seeds. These results may be explained according to Marcos Filho (2005), who stated that prolonged storage exposes seeds for longer periods to adverse conditions such as fungal proliferation and pest incidence, thereby increasing the proportion of dead seeds, as observed in the present study.

According to Guedes et al. (2011) and Vázquez et al. (1991), the accelerated aging technique induces metabolic alterations during the germination process, including changes in respiratory metabolism, membrane integrity, and protein and nucleic acid synthesis. These alterations may inhibit DNA transcription and translation processes, leading to reduced enzymatic activity as a result of protein oxidation and improper folding. Furthermore, Vázquez et al. (1991) reported that DNA polymerase activity is negatively affected by storage.

When comparing results between the two storage periods, cultivar 1 did not exhibit significant differences. However, cultivars 2 and 3, which showed higher vigor indices, displayed clear differences between periods, with increasing storage time significantly reducing the percentage of normal seedlings. This reduction is attributed to greater deterioration of essential seed structures under adverse conditions, thereby defining storage potential and leading to a marked decline in seed physiological quality as storage duration increases. Supporting these findings, Freitas et al. (2000) observed that as storage time increased, the percentage of normal seedlings decreased. Similarly, Resende et al. (2003) reported that prolonged storage intensified the proportion of dead seeds.

CONCLUSIONS

The results demonstrate that wheat genotypes exhibit distinct responses regarding seed longevity and physiological performance during storage. Prolonged storage significantly reduces seed physiological quality, as evidenced by declines in germination, vigor, membrane integrity, and increased proportions of non-viable and dead seeds.

The magnitude of deterioration varied among cultivars, indicating a strong genotype-dependent effect on storage potential. Cultivar 2 consistently maintained higher vigor and membrane integrity throughout the storage periods, whereas cultivar 1 showed greater susceptibility to deterioration, particularly under extended storage conditions.

Overall, storage duration is a critical factor affecting wheat seed physiological potential, and genotype plays a fundamental role in determining seed longevity. These findings reinforce the importance of selecting cultivars with superior storage tolerance and implementing appropriate storage conditions to preserve seed quality and ensure optimal field performance.

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