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RESEARCH ARTICLE

Effect of production environments on storage and physiological quality of maize seed

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ABSTRACT

Storage is a factor that can affect seed quality as a function of latent damages. The losses that most contribute to the reduction in germination and vigor during storage are those caused by humidity, mechanical and temperature-related, that may interfere with seed quality throughout storage. The aim of this study was evaluating the physiological quality of maize seeds produced in two environments and classified in different formats compared to storage periods. The experiment was carried out in the 2016 harvest in two cultivation environments: Entre-Ijuís, RS and Pelotas, RS. Seeds were stratified by thickness through sieves with oblong holes and stratified into small round, large round, small flat and large flat. Growing environments influence the physiological characteristics of maize seeds. The flat and large format seeds have superior physiological quality for the measured physiological characters. The small and round seeds present lower values for germination, first germination count, emergence speed index, shoot dry matter of emergence seedlings and shoot dry matter of germination seedlings. Corn seeds when stored under controlled conditions remain for long periods without causing decreases in physiological quality.

Keywords: *Zea mays*, physiological potential, photoassimilates, seed shape, seed storage, post-harvest practices.

INTRODUCTION

The post-harvest practices that comprise the cleaning, drying, processing and storage stages are fundamental to maintain the high quality of the seed lot, being a determinant factor to avoid possible quality reductions (Peske, Villela, & Meneghello, 2012). The seeds after harvesting undergo changes due to the metabolic process, which may lead to a reduction in the quality of the seeds, being the storage an advantageous and essential solution for the farmer, because it reduces costs with distant transports (Struiving et al., 2013). And to improve levels of seed deterioration, maintaining their quality from the point of physiological maturity to the sowing of these seeds (Peske et al., 2012).

Storage is a factor that can affect seed quality as a function of latent damages (Cunha, Oliveira, Santos, & Mion, 2009). The losses that most contribute to the reduction in germination and vigor during storage are those caused by humidity, mechanical and temperature-related, that may interfere with seed quality throughout storage. Among these factors, moisture in excess during storage accelerates metabolism, increases deterioration and leads to the emergence of pathogens (Moreano et al., 2011; Meneghello, 2014).

The temperature is also an important factor for the conservation of the seeds, in studies with rice seeds it was observed that this can directly affect the speed of the biochemical processes, increase the activity of the enzyme amylase (Aguiar et al., 2015). The reduction of temperature is an effective strategy to preserve the quality of stored seeds (Demito & Afonso, 2009). So, it is essential to understand in advance the storage potential of a seed lot for the seed industry (Grisi & Santos, 2007). There are factors that help in the seed storage potential, among them, genetic, structural factors, degree of humidity, mechanical damages among others, that result in different effects due to the methodology used, adopted method of drying, storage variations and types of packages. Seeds that are more vigorous submitted to unfavorable storage conditions present better storage behavior when compared to less vigorous seeds (Nascimento, 2009). In this context, this work had the aim of evaluating the physiological quality of maize seeds produced in two environments and classified in different formats compared to storage periods.

MATERIAL AND METHODS

Conduction of study

The work was conducted in the didactic laboratory of Seed Analysis belonging to the Department of Plant Science of the Federal University of Pelotas. Representative samples of maize genotypes produced in two environments located in Pelotas - RS were collected at coordinates 31º 52'00 'S and 52º21'00' W and Entre Ijuís, RS referring to the coordinates of 28º21 '32 "S and 54º 16' 04" W.

For seed production, sowing was done manually on October 17th, 2016 (Entre Ijuís - RS) and October 21st, 2016 (Pelotas - RS). Fertilization and correction of soil acidity were previously performed based on soil analysis for both environments, according to the recommendation of the Manual of Fertilization and Liming for the RS and SC States (Comissão de Química e Fertilidade do Solo RS/SC [CQFS RS / SC], 2004). The management of the crop followed the technical recommendations for the maize crop. The mean and minimum values of air temperature, solar radiation, relative air humidity and rainfall were observed during the conduction of the experiment in the growing environments, and their monthly averages are presented in Figure 1.

The seeds were harvested in cobs with approximately 35% moisture, after being sent to the Seeds Laboratory of the Postgraduate Program in Science and Technology of Seeds of the Eliseu Maciel School of Agronomy, Federal University of Pelotas to perform drying until 12 % humidity, whereby the seeds were threshed and beneficiated in order to remove any undesirable impurities. Stratification of the seeds by thickness occurred through sieves of oblong holes, where the material retained in the 7 x 15 mm and 8 x 15 mm sieves was called rounds and the material passing through the 6 x 20 mm and 5 x 19 mm sieves was considered flat seeds. After wards, the seeds were stratified into small round, large round, small flat, and large flat, through round hole sieves. The seeds that passed the 8.5 mm sieve were considered small, those that were retained were considered large. This stratification was performed for the seeds produced in both environments.

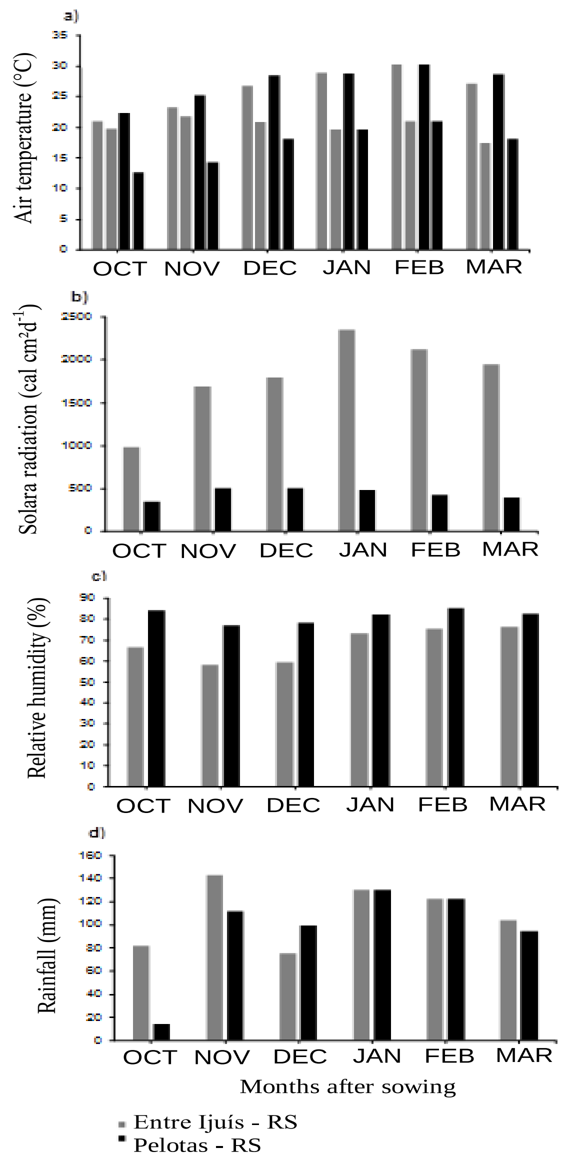

Figure 1. Maximum and minimum air temperature (a), mean solar radiation (b), relative air humidity (c) and rainfall (d) for the municipalities of Entre Ijuís, RS and Pelotas, RS.
Source: National Institute of Meteorology (São Luiz Gonzaga, RS) and Agroclimatological Station of Pelotas-RS (Campus Capão do Leão, RS, Brazil), 2016.

Subsequent to the stratification, the seeds were sent to storage in a cold chamber with a temperature of approximately 15°C and relative humidity of 65% in the seed laboratory of the Postgraduate Program in Seed Science and Technology. The seeds were stored for nine months, and every three months, the samples were collected to perform the physiological quality tests for periods of 0: test after harvest; 3: three months of storage; 6: six months storage, 9: nine months storage. To evaluate the influence of the environment in which the seeds were produced, these being the seeds format and storage periods, the following laboratory tests were performed:

Traits measured

Germination: evaluated from 400 seeds, divided into 8 subsamples of 50 seeds for each environment, format and storage period. The seeds were distributed in germitest paper and moistened with the equivalent of three times the mass of the paper, directed to the germinator with temperature of 25ºC. Seedlings considered normal were counted seven days after sowing and the results expressed as percentage of normal seedlings as recommended by the Rules for Seed Analysis (Ministério da Agricultura, Pecuária e Abastecimento [MAPA], 2009).

First germination count: carried out in along with the germination test, where the percentage of normal seedlings present on the fourth day after the test installation was computed (MAPA, 2009). In addition to the first germination count, ten normal seedlings were collected, separating the aerial part of the root with the aid of a scalpel and shoot, where they were packed in brown paper in an oven 70 ± 2 ° C until the constant mass, results were expressed in grams.

Cold test: determined from four samples subdivided into four fractions of 50 seeds for each environment, format and storage period. The seeds were distributed on germitest paper moistened with distilled water equivalent to three times their dry mass, after seeding the rolls were placed inside plastic bags and these were kept in B.O.D. incubator regulated at 10°C for seven days, then the rollers were transferred to a germinator set at 25°C where they remained for another four days. The evaluation of the germination was carried out according to the recommendations contained in the Rules for Seed Analysis (MAPA, 2009).

Tray emergence: Two hundred seeds were used and arranged in eight replicates of 25 seeds for each environment, format and storage period, being sown in soil with depth of three centimeters. The seedling emergence percentage was evaluated at 15 days after sowing. Together with the emergency tray test, the emergency speed index was performed through the daily counts with standard schedules. At the end of the emergency test 10 seedlings of each treatment were collected to evaluate the dry matter of the shoot and roots being separated and conditioned in brown paper in the greenhouse 70 ± 2°C, results expressed in grams.

Experimental design and Statistical anlysis

The experimental design was completely randomized in a factorial scheme, with 2 (seed production environments) x 4 (seed formats) x 4 (storage periods), arranged in eight replications per treatment. The data obtained in each evaluation were submitted to analysis of variance by the F test, at 5% probability, where the assumptions of the statistical model were verified. The diagnosis of the interaction between seed production environments x seed formats x storage periods, at 5% probability, was performed. When the interaction was significant, the simple effects for the qualitative variation factors (production environments and seed formats) were dismembered.

The quantitative levels were submitted to linear regression where the highest significant degree of the polynomial for each level of qualitative treatment was verified by the t test at 5% probability. The characters that did not show interaction were submitted to the dismemberment of the main effects through the complementary analyzes by Tukey at 5% of probability for qualitative variation factors; in general, for the quantitative data, a linear regression with adjustment of the highest degree of the polynomial at 5% by the t test was performed.

RESULTS AND DISCUSSION

For the germination character there was a significant interaction between the storage periods and the seed production environments. For the Pelotas - RS environment storage periods did not influence germination. For the seeds from Entre Ijuís, RS, the germination was adjusted with a quadratic trend curve and minimum point at 5 months of storage (Figure 1a). For this same variable, significant interaction was obtained between the seed formats x growing environments, regardless of the seed format, the Pelotas - RS environment had higher germination than Entre Ijuís, RS. When comparing the seed formats within each environment, Entre Ijuís, RS showed higher germination when the seeds were large flat and small flat, in contrast (Table 1), lower germination was revealed for the small round seeds. For Pelotas - RS the seed formats did not influence the germination.

Popcorn seeds with flat and large format evidence a higher percentage of germination (Carneiro et al., 2003). According to Carvalho and Nakagawa (2012), both the shape and the size of the seeds did not result in effects on the germination of the seeds. However, the vigor of the seeds could be affected. It should be noted that even though there were differences between the formats and the growing environments, the percentages of germination were higher than 85%, being above the marketing standards for the species (MAPA, 2013).

Similar to germination, the first germination count character revealed interaction between the storage periods x seed production environments, where Pelotas - RS did not express effects on the first germination count versus the storage periods. For Entre Ijuís, RS, the first germination count was adjusted to the quadratic trend curve with a minimum efficiency point at 5 months of storage (Figure 1b). With respect to the interaction between seed formats and growing environments, Environment of Pelotas, RS, was considered superior to Entre Ijuís, RS, being this specific for the large and small flat seeds where they show superiority for the first germination count in relation to the round seeds (Table 1).

Table 1. Average results of the interaction between formats and growing environments for germination and first germination count.

Germination (%)		
Formats	Entre Ijuís-RS	Pelotas-RS
LF[(1)]	88 aB[1]	99 aA
SF	90 aB	98 aA
LR	86 bB	98 aA
SR	84 cB	98 aA
CV (%) 3.46		
First germination count (%)		
Formats	Entre Ijuís-RS	Pelotas-RS
LF	88aB	99 aA
SF	90aB	99 aA
LR	83 bB	98 aA
SR	83 bB	97 aA
CV (%) 4.10		

[1]Averages followed by the same lowercase letter in the column and the same uppercase letter in the row do not differ by the tukey test at the 5% error probability level. [(1)] LF large flat; SF small flat; LR large round; SR small round. CV coefficient of variation.

The environment in which the seeds are produced is closely related to seed and plant development, and unfavorable environments may lead to reduced vigor and physiological potential of seeds (Peske et al., 2012; Szareski et al., 2018a; Szareski et al., 2018b). It was evident that in Pelotas - RS the seeds were formed under more favorable conditions than in Entre Ijuís - RS, because in addition to the greater vigor revealed by the first germination count, the seeds produced in this place maintained their quality even stored during nine months. Research by Kikuti, Vasconcelos, Marincek and Fonseca (2003) define that round seeds located at the apex of the spike, present inferior performance and confirm the tendencies obtained in this study. For Trogello et al. (2012), the sizes and formats of corn seeds do not influence abruptly the first germination count. But for Vazquez, Arf, Sargi, Cesar and Pessoa (2012), these effects were proniable in the early development of plants.

The emergence of seedlings evidenced interaction between storage periods and growing environments. For Pelotas - RS the emergency adjusted linearly with decrease while the storage periods tended to nine months. This decrease was of the order of 4% in relation to the seeds that were analyzed soon after harvest and correspond to zero months of storage (Figure 2c). For Entre Ijuís, RS, the emergency was adjusted with a quadratic trend curve reaching a point of minimum efficiency at seven months of storage (Figure 2c). The unfolding of the interaction between the storage periods and growing environments showed that regardless of the periods the corn seeds are stored, the emergence of the seedlings of the seeds that were produced in Pelotas, RS, (Table 2) were larger.

The accumulation of seed reserves occurs through the translocation of photoassimilates from the plants to the seeds after the fertilization. Several factors may influence seed vigor in the field, among them the environmental conditions that the plants undergo during their formation, where vigor is the reflection of the interaction of these conditions with the mother plant during the production of the seeds (Carvalho & Nakagawa, 2012). The emergence in the field reflected these conditions, being possible to verify that the seeds produced in Pelotas - RS revealed a greater emergency throughout the periods of storage without reducing the quality.

Table 2. Un folding of the interaction between growing environments x storage periods for the variables emergence, emergency speed index (ESI) and shoot dry mass of the emergency.

Seedlings emergence (%)		
Storage periods(1)	Entre Ijuís, RS	Pelotas, RS
0	88 B[1]	96 A
3	84 B	96 A
6	76 B	92 A
9	76 B	92 A
CV (%) 9.43		
ESI		
Storage periods	Entre Ijuís, RS	Pelotas, RS
0	2.79 B	3.35 A
3	1.86 B	2.43 A
6	2.61 B	3.63 A
9	3.14 B	4.06 A
CV (%) 17.89		
Shoot dry mass of the emergency (g)		
Storage periods	Entre Ijuís, RS	Pelotas, RS
0	0.64 A	0.57 B
3	0.85 A	0.67 B
6	0.68 A	0.65 A
9	0.67 A	0.60 B
CV (%) 4.10		

[1]Averages followed by the same letter in the column do not differ from each other by the Tukey test at 5% of error probability. (1) Periods of storage: 0 (after harvest); 3 (3 months storage); 6 (6 months of storage); 9 (9 months storage). CV coefficient of variation.

Seedling emergence revealed significant effects only for seed format, where large and small flat seeds had the highest percentages of seedling emergence (Table 3). The seeds with the large round shape are the first ones that are formed in the spike, so any delay in harvest can intensify the deterioration process and reduce the vigor of the seeds produced (Marcandalli, Lazarini, & Malaspina, 2011). Research by Sangoi et al. (2004) showed that seed size, sowing depth, and initial corn growth are closely related to the percentage of emergence.

The emergence speed index for both environments was adjusted to the quadratic trend curve, with a minimum point between three and four months of storage (Figure 2d). The unfolding of the interaction of the storage periods x growing environments obtained a superior emergency speed index for Pelotas-RS independent of the storage period (Table 2) tested. Large and small flat, and large round seeds revealed higher values (Table 3) for this character.

The higher the value of the emergence speed index, the higher the seed vigor. This is related to the capacity of membrane system reorganization, hydrolysis and metabolization of the reserves, as well as its use by the embryo during imbibition and resumption of growth (Bewley & Black, 2013; Marcos Filho, 2015). Stumm, Ludwig and Schmitz (2016) revealed that flat and large seeds obtained a higher emergence speed index with slower germination.

The data of the shoot dry mass of the seedlings revealed interaction between the periods of storage and growing environments. For Entre Ijuís, RS the maximum response of this character was expressed in four months of storage, in contrast, Pelotas - RS determined its maximum at five months of storage (Figure 2e). The unfolding of the simple effects of the interaction determined that at zero, three and nine months of storage the seeds produced in Entre Ijuís, RS express a higher shoot dry mass in relation to those produced in Pelotas - RS. Size is a characteristic of seed quality that influences seedling growth and development (Sulewska et al., 2014). Because larger seeds are generally better nourished during their development, they possess well-formed and with more reserve embryos, which are more vigorous. For Soares, Santos, Simões, Pazzin and Silva (2015), large seeds originate plants with greater shoot dry mass. Martinelli-Seneme, Zanotto and Nakagawa (2000) define that seeds of larger size originate seedlings with higher dry matter. Seeds of smaller size germinate faster than larger ones. However, the larger seedlings give rise to larger mass seedlings. Sulewska et al. (2014) state that although germination is faster, seedling size and water absorption capacity were lower in seeds with small dimensions.

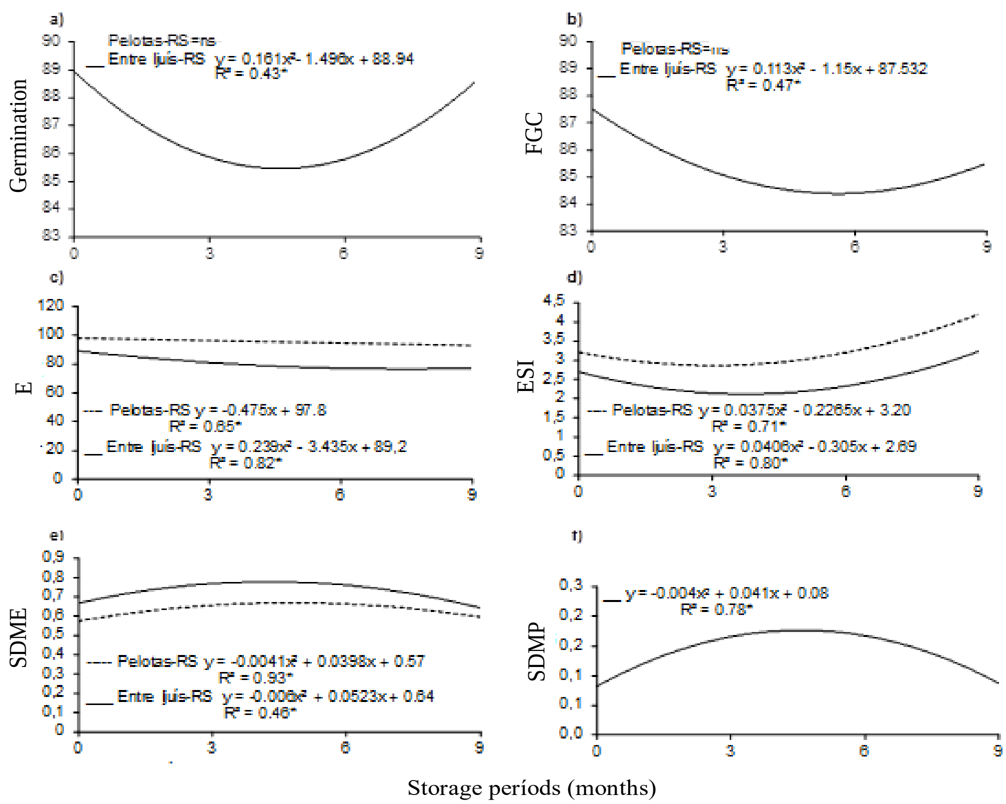

Figure 2. Interaction between growing environment x storage periods for a) germination, b) first germination count (FGC), c) emergency, d) emergency speed index (ESI), e) shoot dry mass of the emergency (SDME) and f) regression to shoot dry mass (SDM) as a function of storage periods. (Significance level of * 5% and ns non significant).

The seedlings root dry mass of the emergency was identified interaction between the periods of storage x seed format x growing environments (Figure 3a). For the seeds produced in Entre Ijuís, RS of large flat format, large round and small round, they were adjusted to the quadratic trend curve with minimum point at seven months of storage for large flat and large round seeds with six months to small round. For the small flat shape of the seeds produced in Entre Ijuís, RS, the root dry mass of the seedlings decreased linearly with increased storage periods (Figure 3a). For Pelotas - RS, all seed formats were adjusted to a quadratic trend curve with a minimum root dry mass point at five months of storage for large flat, large round and small round seeds at six months of storage for the small flat (Figure 3a).

Table 3. Average results for emergence, emergency speed index (ESI) and shoot dry mass of emergency according to the formats.

Formats	Seedlings emergence (%)
LF[(1)]	91 a[1]
SF	91 a
LR	85 b
SR	87 ab
CV (%) 9.43	
Formats	ESI
LF	3.12 a
SF	3.12 a
LR	3.00 a
SR	2.70 b
CV (%) 17.89	
Formats	Shoot dry mass of emergency (g)
LF	0.74 a
SF	0.63 b
LR	0.74 a
SR	0.59 b
CV (%) 17.80	

[1]Averages followed by the same letter in the column do not differ from each other by the Tukey test at 5% of error probability. [(1)] LF large flat; SF small flat; LR large round; SR small round. CV coefficient of variation.

The unfolding of the interaction simple effects for storage periods x seed format x growing environments (Table 4). In the comparison between the formats within each growing environment, Entre Ijuís, RS showed better results in the absence of storage for root dry mass of seedlings from large round seeds. At three months of storage the small round seeds obtained the lowest root dry mass. For the seeds produced in Pelotas - RS, only at nine months of storage there were significant differences between the formats, being the largest dry mass of the root originated from large flat seeds. For Carvalho and Nakagawa (2012), seeds of larger size have tissues of more voluminous reserves and seedlings of greater mass.

In the comparison of the growing environments, the root dry mass of the seedlings from zero to three months of storage did not differ. At six months of storage, the small flat seeds were superior to Entre Ijuís, RS. At nine months of storage, there were no significant differences between the growing environments for each seed format (Table 4). The dry mass of the roots is an important attribute that can favor establishment in the field, being an indication of quality, because corn seeds with higher quality tend to present superiority to the dry mass of roots (Sbrussi & Zucareli, 2014).

The shoot dry mass of the seedlings collected at the first germination count was significant for the storage periods, which obtained maximum point at five months of storage (Figure 1f). For Pelotas - RS it was verified superiority for the shoot dry mass, being these superiors for the large flat and small flat format (Table 5). These results are partly explained by the fact that the larger and flatter seeds have a greater accumulation of photoassimilates, which are transferred to the seedlings (Amaral, Medeiros, Menezes, Luz, Pivoto, & Bialozor, 2012). Thus, these seeds will have a faster establishment, larger initial starter and will be vigorous (Oliveira, Martins, Silva, & Vieira, 2009).

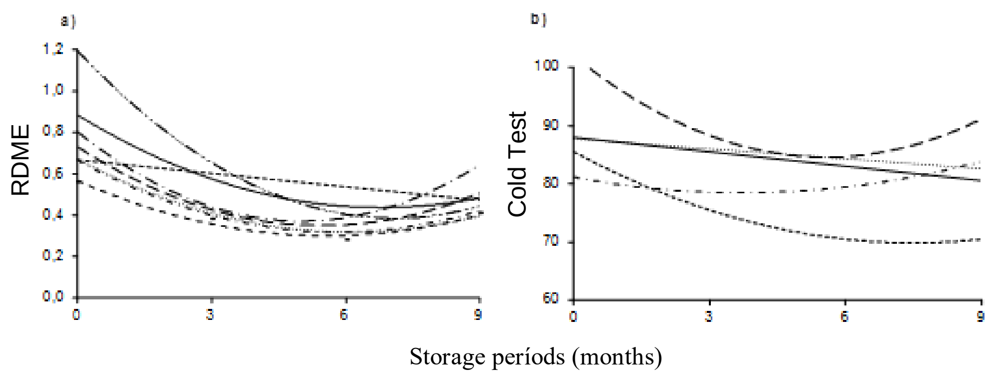

Figure 3. Interaction of growing environments x formats x storage periods for a) root dry mass of the emergence (RDME), where (____) Entre Ijuís-RS LF $y= 0.0097x^2-0.1318x+0.8845$ $R^2=0.6672$; (------) Entre Ijuís-RS SF $y=-0.022x+0.669$ $R^2=0.6521$; (__..__..__) EntreIjuís-RS LR $y=0.0161x^2-0.2283x+1.195$ $R^2=0.9694$; (_._._.) Entre Ijuís-RS SR $y= 0.0103x^2-0.1195x+0.6665$ $R^2=0.9249$; (__.__.__) Pelotas-RS LF $y=0.0172x^2-0.1723x+0.803$ $R^2=0.8342$; (......) Pelotas-RS SF $y=0.0094x^2-0.1157x+0.673$ $R^2=0.7658$;(__ __) Pelotas-RS LR $y=0.0128x^2-0.1397x+0.731$ $R^2=0.7048$; (- - - -) Pelotas-RS SR $y = 0.0086x^2-0.0958x+0.5675$ $R^2=0.9721$; b) coldtest, (___) Entre Ijuís-RS LF $y=-0.838x+88$ $R^2=0.75$; (......) Entre Ijuís-RS SF $y=-0.495x+87.8$ $R^2=0.43$; (------) Entre Ijuís-RS LR $y=0.269x^2-4.166x+86$ $R^2=0.78$; (_._._.) Entre Ijuís-RS SR $y=0.2261x^2-1.72x+81.15$ $R^2=0.91$; Pelotas-RS LF y=ns; Pelotas-RS SF y=ns; Pelotas LR y=ns; (_ _ _) Pelotas-RS SR $y=0.527x^2-5.93x+101.7$ $R^2=0.48$; LF large flat; SF small flat; LR large round; SR small round. (Significance level of * 5% and ns Not significant).

For the cold test there was interaction between the storage periods x seed formats x growing environments. Seeds produced in Entre Ijuís, RS, of large and small flat format, decreased linearly with increasing storage time up to nine months. This decrease in seed vigor revealed that the increase in the storage period up to nine months reduced by 8% for large flat seeds and 5% for small flat seeds. In this same production environment, large and small round seeds conformed to a quadratic trend curve with a minimum vigor point at eight months for large round seeds and four months for small round seeds (Figure 3a). For Pelotas,RS, the formats of large and small flat and large round seeds revealed that the vigor of the seeds did not change due to storage periods. For seeds the small round shape in this same growing environment was specific to a minimum of six months storage vigor (Figure 3a).

The unfolding of the simple effects of the interaction between storage periods x seed format x growing environments. It was evidenced that Entre Ijuís, RS, when the seeds were evaluated soon after the harvest, where the greatest vigor occurs for the large flat and small flat formats, however, did not differ statistically from the large rounds. At three months of storage, the large and small flat seeds showed superiority to vigor. In relation to the six months of storage, the large flat, small flat and round seeds were superior, and at nine months, the small flat seeds had higher magnitudes (Table 4). Among the growing environments, the large flat, small flat and round seeds produced in Pelotas, RS, resulted in greater vigor throughout the storage.

Table 4. Mean results of the significant interaction between environments (Entre Ijuís and Pelotas) x formats (large flat, small flat, large round, small round) x storage periods (0, 3, 6, 9 months) for the characters cold test, root dry mass of the emergency, shoot length and stem diameter.

Cold test (%)								
	Entre Ijuís, RS				Pelotas, RS			
Storage periods[1]	LF	SF	LR	SR	LF	SF	LR	SR
0	86 Aβ[2]	88 Aβ	84 ABβ	81 Bβ	99 Aα	97 Aα	99 Aα	99 Aα
3	89 Aβ	88 Aβ	80 Bβ	79 Bβ	98 Aα	96 Aα	98 Aα	97 Aα
6	82 Aβ	80 Aβ	66 Bβ	79 Aα	98 Aα	96 Aα	96 Aα	76 Bα
9	80 Bβ	85 Aβ	72 Bβ	84 ABβ	99 Aα	95 Aα	99 Aα	94 Aα
CV (%) 3.93								
Root dry mass of the emergency								
	Entre Ijuís, RS				Pelotas, RS			
Storage periods[1]	LF	SF	LR	SR	LF	SF	LR	SR
0	0.83 Bα[2]	0.71 Bα	1.17 Aα	0.65 Bα	0.77 Aα	0.64 Aα	0.69 Aβ	0.56 Aα
3	0.74 Aα	0.58 ABα	0.73 Aα	0.45 Bα	0.54 Aα	0.51 Aα	0.55 Aβ	0.38 Aα
6	0.28 Aα	0.46 Aα	0.33 Aα	0.27 Aα	0.29 Aα	0.22 Aβ	0.23 Aα	0.28 Aα
9	0.54 Aα	0.53 Aα	0.47 Aα	0.44 Aα	0.68 Aα	0.43 Bα	0.55 ABα	0.41 Bα
CV (%) 31.74								

[1]Periods of storage: 0 (after harvest); 3 (3 months storage); 6 (6 months of storage); 9 (9 months storage). [(1)] LF large flat; SF small flat; LR large round; SR small round. CV coeficiente of variation. [2]Means followed by the same capital letter in the line to format within each environment and the same Greek letter for environment within each cultivation format do not differ from each other by the Tukey's test at the level of 5% probability of error.

The cold test provides extreme conditions of low temperature that limits the probability of survival of the less vigorous seeds, since the low temperature can reduce the speed of germination of the seeds (Barros, Dias, Cicero, & Krzyzanowski, 1999). The seeds that are located at the base of the spike are more susceptible to the fungus action, because in this region a greater amount of water accumulation occurs in relation to the other parts of the spike, causing an increase in the water content of the seeds and, consequently, vigor reduction. In this sense, the seeds located in the middle third and at the apex of the spike are more protected and may perform better than those located at the base (Kikuti et al., 2003).

Research by Mondo and Cicero (2005) revealed that the quality of corn seeds located at different positions in the spike before the cold test determines that intermediate and flattened seeds are the best. Martinelli-Seneme et al. (2000), define that flattened seeds are more vigorous than the round ones. They are less mechanically damaged compared to medium seeds, leading to a higher rate of deterioration (Peterson, Perdomo, & Burris, 1995). In general, seed format and environmental characteristics influence the physiological quality of maize seeds, being these starches and providing storage conditions for up to nine months maintaining the physiological quality of the seeds.

Table 5. Mean results for shoot dry mass of seedlings (SDMS) as a function of the growing environment and according to the seed formats.

Environments	SDMS (g)
Entre Ijuis-RS	0.11 b[1]
Pelotas-RS	0.13 a
Formats	SDMS (g)
LF[2]	0.12 ab
SF	0.14 a
LR	0.12 bc
SR	0.10 c
CV (%) 36.80	

[1]Averages followed by the same letter in the column do not differ from each other by the Tukey test at 5% of error probability. [2]LF large flat; SF small flat; LR large round; SR small round. CV coefficient of variation.

CONCLUSIONS

Growing environments influence the magnitude of the physiological characteristics of maize seeds. The flat and large format seeds have superior physiological quality for the measured physiological characters.

The small and round seeds present lower values for germination, first germination count, emergence speed index, shoot dry matter of emergence seedlings and shoot dry matter of germination seedlings.

Corn seeds when stored under controlled conditions remain for long periods without causing decreases in physiological quality.

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REFERENCES

Aguiar, R. W. S., Brito, D. R., Lopes, M. M., Santos, G. R., Sousa, C. M., Silva, E. M. M., & Didonet, J. (2015). Physiological and enzymatic changes in rice seeds stored at low temperatures. *African Journal of Biotechnology*, *14*(31), 2434–2441. https://doi.org/10.5897/ajb2015.14568

Amaral, A. D. I., Medeiros, S. L. P., Menezes, N. L., Luz, G. L., Pivoto, D., & Bialozor, A. (2012). Qualidade de sementes de canola classificadas por densidade. *Revista Brasileira de Sementes*, *34*(2), 302–309. https://doi.org/10.1590/S0101-31222012000200016

Barros, A. S. R., Dias, M. C. L. L., Cicero, S. M., & Krzyzanowski, F. C. (1999). Testes de frio. In Krzyzanowski, F. C., Vieira, R. D., & França Neto, J. B. (Eds.), *Vigor de sementes: conceitos e testes* (pp. 1–15). Londrina, PR: ABRATES.

Bewley, J. D., & Black, M. (2013). *Seeds: physiology of development, germination and dormancy* (3rd ed.). New York, USA: Springer-Verlag.

Carneiro, V., Araújo, E. F., Miranda, G. V., Galvão, J. C. C., Reis, M. S., & David, A. M. S. S. (2003). Efeito da Debulha e da Classificação sobre o Tamanho e a Qualidade de Sementes de Milho-Pipoca. *Revista Brasileira de Milho e Sorgo*, *2*(1), 97–105. https://doi.org/10.18512/1980-6477/rbms.v2n1p97-105

Carvalho, N. M., & Nakagawa, J. (2012). *Sementes: ciência, tecnologia e produção* (5th ed.). Jaboticabal, SP: Funep.

CQFS-RS/SC – Comissão de Química e Fertilidade do Solo RS/SC. (2004). *Manual de Adubação e de Calagem para o Estado do Rio Grande do Sul e Santa Catarina* (10th ed.). Porto Alegre, RS: SBCS/Núcleo Regional Sul, UFRGS.

Cunha, J. P. A. R., Oliveira, P., Santos, C. M., & Mion, R. L. (2009). Qualidade das sementes de soja após a colheita com dois tipos de colhedora e dois períodos de armazenamento. *Ciência Rural*, *39*(5), 1420–1425. https://doi.org/10.1590/s0103-84782009005000063

Demito, A., & Afonso, A. D. L. (2009). Qualidade das sementes de soja resfriadas artificialmente. *Engenharia Na Agricultura*, *17*(1), 7–14.

Grisi, P. U., & Santos, C. M. (2007). Influência do armazenamento, na germinação das sementes de girassol. *Horizonte Científico*, *1*(1), 14–18.

Kikuti, A. L. P., Vasconcelos, R. C., Marincek, A., & Fonseca, A. H. (2003). Desempenho de sementes de milho em relação à sua localização na espiga. *Ciência e Agrotecnologia*, *27*(4), 765–770. https://doi.org/10.1590/s1413-70542003000400004

MAPA - Ministério da Agricultura, Pecuária e Abastecimento. (2009). *Regras para análises de semente* / Ministério de Agricultura, Pecuária e Abastecimento. Secretaria de Defesa Agropecuária. Brasília: MAPA/ACS,399p.

MAPA - Ministério da Agricultura, Pecuária e Abastecimento. (2013). *Instrução Normativa nº 45, de 17 de setembro de 2013*. Diário Oficial da República Federativa do Brasil, Ministério da Agricultura, Pecuária e Abastecimento, Brasília, DF, Sep 20th, 2013. *Section I*, 38p.

Marcandalli, L. H., Lazarini, E., & Malaspina, I. C. (2011). Épocas de aplicação de dessecantes na cultura da soja: Qualidade fisiológica de sementes. *Revista Brasileira de Sementes*, *33*(2), 241–250. https://doi.org/10.1590/S0101-31222011000200006

Marcos Filho, J. (2015). *Fisiologia de sementes de plantas cultivadas* (2nd ed.). Londrina, PR: ABRATES.

Martinelli-Seneme, A., Zanotto, M. D., & Nakagawa, J. (2000). Efeitos da forma e do tamanho na qualidade de sementes de milho, cultivar AL-34. *Revista Brasileira de Sementes*, *22*(1), 232–238. https://doi.org/10.17801/0101-3122/rbs.v22n1p232-238

Meneghello, G. E. (2014). Qualidade de sementes: umidade e temperatura. *Seeds News*, *18*(6), 28–32.

Mondo, V. H. V., & Cicero, S. M. (2005). Análise de imagens na avaliação da qualidade de sementes de milho localizadas em diferentes posições na espiga. *Revista Brasileira de Sementes*, *27*(1), 9–18. https://doi.org/10.1590/s0101-31222005000100002

Moreano, T. B., Braccini, A. L., Scapim, C. A., Krzyzanowski, R. C., Francaneto, J. B., & Marques, O. J. (2011). Changes in the effects of weathering and mechanical damage on soybean seed during storage. *Seed Science and Technology*, *39*(3), 604–611. https://doi.org/10.15258/sst.2011.39.3.07

Nascimento, W. M. (2009). *Tecnologia de sementes de hortaliças*. Brasília, DF: Embrapa Hortaliças.

Oliveira, A. C. S., Martins, G. N., Silva, R. F., & Vieira, H. D. (2009). Testes de vigor em sementes baseados no desempenho de plântulas. *Inter Science Place*, *1*(4), 12–16.

Peske, S. T., Villela, F. A., & Meneghello, G. E. (2012). *Sementes: Fundamentos Científicos e Tecnológicos* (3rd ed.). Pelotas, RS: UFPel.

Peterson, J. M., Perdomo, J. Á., & Burris, J. S. (1995). Influence of kernell position mechanical damage and controlled deterioration on estimats of hybrid maize seed quality. *Seed Science & Technology*, *23*(3), 647–657.

Sangoi, L., Almeida, M. L., Horn, D., Bianchet, P., Gracietti, M. A., Schmitt, A., & Schweitzer, C. (2004). Tamanho de semente, profundidade de semeadura e crescimento inicial do milho em duas épocas de semeadura. *Revista Brasileira de Milho e Sorgo*, *3*(3), 370–380. https://doi.org/10.18512/1980-6477/rbms.v3n3p370-380

Sbrussi, C. A. G., & Zucareli, C. (2014). Germinação de sementes de milho com diferentes níveis de vigor em resposta à diferentes temperaturas. *Semina:Ciencias Agrarias*, *35*(1), 215–226. https://doi.org/10.5433/1679-0359.2014v35n1p215

Soares, M. M., Santos, H. C., Simões, M. G., Pazzin, D., & Silva, L. J. (2015). Estresse hídrico e salino em sementes de soja classificadas em diferentes tamanhos. *Pesquisa Agropecuaria Tropical*, *45*(4), 370–378. https://doi.org/10.1590/1983-40632015v4535357

Struiving, T. B., Machado, D. L. M., Santos, D., Siqueira, D. L., Lucena, C. C., & Matarazzo, P. H. M. (2013). Qualidade fisiológica de sementes de citros durante o armazenamento em ambiente refrigerado. *Ciencia Rural*, *43*(10), 1777–1782. https://doi.org/10.1590/S0103-84782013001000008

Stumm, S. B. Q., Ludwig, F., & Schmitz, J. A. K. (2016). Qualidade fisiológica de sementes de milho em função de tamanho, formato e tratamento. *Scientia Agraria Paranaensis*, *15*(2), 222–227.

Sulewska, H., Smiatacz, K., Szymanska, G., Panasiewics, K., Bandurska, H., & Glowick-awoloszyn, R. (2014). Seed size on yield quantity and quality of mayze (*Zea mays* L.) cultivated in South East Baltic region. *Zemdirby state Agriculture* *101*(1), 35–40. https://doi.org/10.13080/z-a.2014.101.005

Szareski, V. J., Carvalho, I. R., Demari, G. H., Pelissari, G., Pelegrin, A. J., Barbosa, M. H., Rosa, T. C., Santos, N. L., Martins, T., Nardino, M., Pedo, T., Souza, V. Q., & Aumonde, T. Z. (2018a). Path analysis applied to agronomic traits of contrasting growth habit soybeans. *Australian Journal of Crop Science*, *12*, 531–538.

Szareski, V. J., Carvalho, I. R., Kehl, K., Pelegrin, A. J. de, Nardino, M., Demari, G. H., … Souza, V. Q. de. (2018b). Interrelations of Characters and Multivariate Analysis in Corn. *Journal of Agricultural Science*, *10*(2), 187. https://doi.org/10.5539/jas.v10n2p187

Trogello, E., Modolo, A. J., Carnieletto, R., Kolling, E. M., Scarsi, M., & Sgarbossa, M. (2012). Desenvolvimento inicial e produtividade da cultura do milho no sistema de integração lavoura-pecuária. *Revista Ceres*, *59*(2), 286–291. https://doi.org/10.1590/S0034-737X2012000200019

Vazquez, G. H., Arf, O., Sargi, B. A., Cesar, A., & Pessoa, O. (2012). Influência do tamanho e da forma da semente de milho sobre o desenvolvimento da planta e a produtividade de grãos. *Bioscience Journal*. 28(1): 16-24