Revista Ciência Agronômica, v. 52, n. 4, e20207632, 2021
Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE
www.ccarevista.ufc.br

Scientific Article
ISSN 1806-6690

Physiological quality and dormancy of rice seeds during storage[1]

Qualidade fisiológica e dormência de sementes de arroz durante o armazenamento

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ABSTRACT - Storage is a set of techniques adopted during the off-season, aiming at conditioning the seeds to maintain their quality for the next harvest. The study of effect by storage is important to know the performance of dormancy under different environments and the influence of temperature and relative humidity in the storage on rice seeds. Therefore, the objective was to evaluate the physiological quality of seeds in storage, to understand whether environmental conditions influence in overcoming dormancy and the physiological quality of rice seeds. The experiment was conducted in a completely randomized design in a factorial scheme: storage x evaluation times x cultivar. Seeds of rice cultivars from the Alto Vale do Itajaí, SC, from the 2016/17 and 2017/18 seasons were submitted to storage in a dry chamber (10 ºC and 50% RH) and conventional (without temperature and relative humidity control). Germination, vigor by accelerated aging and tetrazolium tests during storage were performed. Dormancy was affected by storage conditions. And it affected the germination and vigor of the seeds. It is concluded that the temperature and humidity conditions in the storage affect the overcoming of the dormancy of rice seeds. The dry chamber (10 ºC and 50% RH) favors the overcoming of dormancy and the maintenance of the physiological quality of the seeds of the rice cultivars Epagri 109, SCS121 CL, SCS122 Miura and Primoriso CL.

Key words: Germination. Accelerated aging. Dry chamber. Conventional storage. *Oryza sativa*.

RESUMO - O armazenamento é um conjunto de técnicas adotadas durante o período de entressafra visando o condicionamento das sementes para a manutenção da sua qualidade para a próxima safra. O estudo do efeito do armazenamento é importante para se conhecer a performance da dormência sob diferentes ambientes e a influência da temperatura e umidade relativa do ar no armazenamento sobre as sementes de arroz. Portanto, objetivou-se avaliar a qualidade fisiológica das sementes no armazenamento, para compreender se as condições ambientais influenciam na superação da dormência e na qualidade fisiológica das sementes de arroz. O experimento foi conduzido em delineamento inteiramente casualizado em esquema fatorial: armazenamento x tempos de avaliação x cultivar. Foram submetidas ao armazenamento em câmara seca (10 °C e 50% UR) e convencional (sem controle de temperatura e umidade relativa do ar), sementes de cultivares de arroz provenientes da Região do Alto Vale do Itajaí, SC, safras 2016/17 e 2017/18. Realizou-se os testes de germinação, vigor após o envelhecimento acelerado e tetrazólio durante o armazenamento. A dormência foi afetada pelas condições de armazenamento. E afetou a germinação e o vigor das sementes. Conclui-se que as condições de temperatura e umidade no armazenamento afetam a superação da dormência de sementes de arroz. A câmara seca (10 ºC e 50% UR) favorece a superação da dormência e a manutenção da qualidade fisiológica das sementes dos cultivares de arroz Epagri 109, SCS121 CL, SCS122 Miura e Primoriso CL.

Palavras-chave: Germinação. Envelhecimento acelerado. Câmara seca. Armazenamento convencional. *Oryza sativa.*

DOI: 10.5935/1806-6690.20210073
Editor-in-Article: Prof. Alek Sandro Dutra - alekdutra@ufc.br
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Received for publication on 22/09/2020; approved on 11/05/2021
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INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most widely cultivated species in the world and was one of the first to be domesticated (LIMA *et al*., 2019). Consumed on all continents, it plays a strategic role both economically and socially (GARCIA; COELHO, 2021).

It reaches physiological maturity, with moisture around 30% (South-Brazilian Society of Irrigated Rice [SOSBAI], 2018), and from this stage of the plant, the deterioration of seeds begins, being an irreversible and cumulative degenerative process (KAPOOR *et al*., 2011). Therefore, it is necessary to use techniques in harvest and post-harvest, especially in storage, which minimize seed deterioration.

In Brazil, it is usual to store conventional seeds of large crops in environments without any kind of control of environmental conditions. However, temperature and humidity are considered the main causes of seed deterioration in storage (GOLDFARB; QUEIROGA, 2013), and it is important to use appropriate techniques in the off-season to maintain the physiological quality produced in the field.

Conventional storage, depending on the region, can reach inadequate temperatures (> 25 ºC) and relative humidity (> 75%) in storage (SMANIOTTO *et al*., 2014), causing changes in the reserve components, in the chemical composition, in the cell membrane and in the enzymatic activity of the seeds impairing the physiological quality.

However, the effect of the storage condition on the physiological quality of seeds depends on the species. For rice, for example, which presents dormancy for a variable period, due to genetic and environmental factors (BALDI *et al*., 2012), storage is important in the overcoming process. Furthermore, it is possible that the conditions of temperature and humidity of the storage air, influence the overcoming of the dormancy of these seeds.

Thus, the study of the implication of storage conditions is important to know the dormancy performance and physiological quality of rice seeds during the off-season under different conditions. As well, it makes it possible to acquire a better understanding of the effect and importance of temperature and relative humidity in the storage of these seeds, and what would be the ideal conditions for the species (BESSA, 2015), assisting in the decision-making of technicians and producers.

Currently, there are several storage options available in the sector: in bulk, in bulk under controlled temperature conditions, in bags under environmental conditions and in bags under controlled conditions of temperature and/or relative humidity (LABBÉ; VILLELA; PESKE, 2019). Among them, storage in bags/bags under environmental conditions is the most used, but the use of bags/bags under controlled conditions of temperature and relative humidity has been attracting the interest of companies.

The dry chamber is a type of storage that allows control of the temperature (10 ºC) and relative humidity (from 55 to 65%) of the air in the environment. It is possible to perform thermal and hygroscopic insulation (LABBÉ; VILLELA; PESKE, 2019). However, it is not known how rice seeds react to this storage condition.

In general, low air temperatures in storage increase the viability period of orthodox seeds (JOSÉ *et al*., 2010), because it decreases the speed of biochemical and metabolic reactions (AGUIAR *et al*., 2012), and consequently reduces the process of deterioration, favoring the maintenance of the physiological potential of the seeds.

However, the relative humidity of the air in storage is also important because the seeds are hygroscopic, in other words, they have the ability to exchange humidity with the environment (LABBÉ; VILLELA; PESKE, 2019). Therefore, in storage, the synergistic action of the temperature/relative air humidity combinations should be considered (MARCOS FILHO, 2015).

Therefore, this study aimed to evaluate the physiological quality of seeds in storage, to understand whether environmental conditions influence the overcoming of dormancy and physiological quality of rice seeds.

MATERIAL AND METHODS

This research was carried out in the seed analysis laboratory (LAS) located at the Center for Agroveterinary Sciences (CAV) of the State University of Santa Catarina (UDESC) in Lages, Santa Catarina State (SC).

Seeds produced commercially in the Alto Vale do Itajaí (Santa Catarina State) of cultivars Epagri 109, SCSBRS Tio Taka, SCS116 Satoru, SCS121 CL, SCS122 Miura in the 2016/17 season and Epagri 109, SCS121 CL, SCS122 Miura and Primoriso CL in the 2017/18 season were used, shortly after processing.

The design used was completely randomized with four replications, in a factorial scheme cultivar x storage condition x storage time.

Seed sampling was performed to obtain the average sample (1.4 kg) prior to submission for storage and the recommendations of the Rules for Seed Analysis (RAS) were followed (BRASIL, 2009).

Soon after, the seeds were placed in paper bags and submitted to storage conditions in a Von Stein dry chamber (10 °C and 50% RH) and in conventional storage (seed processing unit) of a rice seed producing company, located in the Alto Vale do Itajaí, SC.

To assess the time factor, storage intervals were determined. In the 2016/17 season, seed collections for evaluations were carried out at the beginning of storage (0) and at 30, 60 and 120 days. In the 2017/18 season, the 90-day storage time was added to the intervals previously evaluated.

Physiological evaluations during storage consisted of percentage of germination, dormancy, and vigor by accelerated aging.

The germination test was performed with four replicates of 100 seeds (BRASIL, 2009). The seeds were sown on three sheets of germitest paper, moistened with distilled and deionized water, an amount equivalent to three times the mass of the dry paper. The rolls were placed in a plastic bag and taken to the Mangelsdorf germinator at 25 ± 2 °C for 14 days. The counts occurred at 7 and 14 days after sowing, classifying the seedlings into normal, abnormal, and non-germinated seeds. The percentage of germination was obtained through the arithmetic mean of the repetitions of the result of normal seedlings.

At the end of the germination test, when ungerminated seeds remained, the tetrazolium test was performed to determine viability (dormancy). The seeds were cut longitudinally through the embryo and ¾ of the endosperm, and immersed in a solution of 2,3,5 triphenyl-tetrazolium at a concentration of 0,1% for a period of 3 hours at 35 °C in the dark (BRASIL, 2009). After evaluation, the number of dead (unviable) and dormant (viable) seeds was determined according to the criteria established by the RAS (BRASIL, 2009) and the results were expressed as a percentage of dormant and dead seeds.

In this work, we chose to use only the vigor by accelerated aging, as it presents a high correlation with field emergence (GARCIA; COELHO, 2021). Vigor by accelerated aging was conducted using four replicates of 100 seeds. The seeds were placed on the surface of a stainless-steel screen, positioned above 40 mL of distilled and deionized water, in gerbox (11 x 11 x 3.5 cm) and kept in an accelerated aging chamber at 41 °C for 120 hours (ZUCHI; BEVILAQUA, 2012). Then, the seeds were sown in three sheets of germitest paper, moistened with distilled and deionized water, an amount equivalent to three times the mass of the dry paper, and packed in plastic bags in a Mangelsdorf germinator at a temperature of 25 ± 2 °C for 14 days. Counts were performed at 7 and 14 days after sowing, counting the number of normal and abnormal seedlings and dead seeds. The percentage of vigor was expressed by arithmetic mean of the repetitions of the result of normal seedlings.

The data were submitted to the Shapiro-Wilk test and the Bartlett test for analysis of normality and homogeneity of the data, respectively. Thus, the need to transform the data into percentages was identified, by arc sine, to meet the assumptions, but the data presented are the unprocessed values. Then, analysis of variance (ANOVA) ($p < 0.05$) was carried out. And the means were compared by the Tukey test ($p < 0.05$). Regression analysis was also performed with polynomial adjustment and with the application of the t test ($p < 0.05$), as well as the coefficient of determination.

All statistical analyses were performed using the R software version 1.1.456 (R CORE TEAM, 2018).

RESULT AND DISCUSSION

In the 2016/17 season, the cultivar Epagri 109 had the highest percentage of germination (80%) after harvest, differing statistically from the other cultivars, while SCS122 Miura had the lowest, 44% (Figure 1A). This performance indicates the occurrence of different degrees of dormancy among rice cultivars, demonstrating that dormancy is affected by the genotype and by the edaphoclimatic conditions of production.

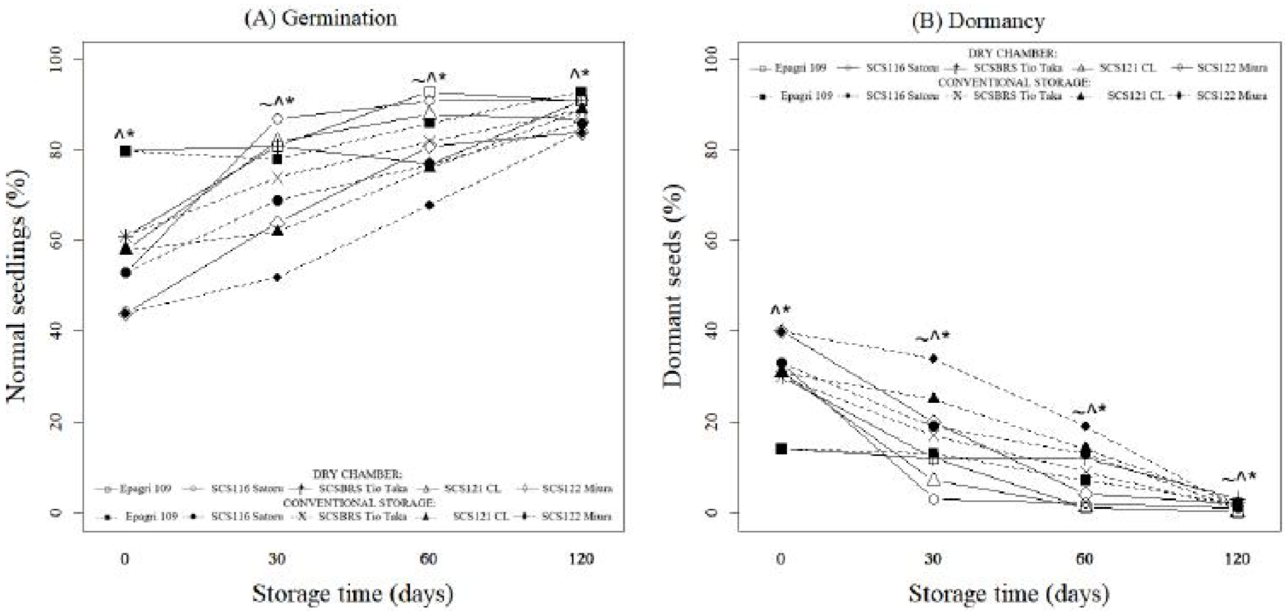
In most cultivars, except for Epagri 109, there were high percentages of dormant seeds (up to 30%) after harvest (Figure 1B). According to Penfield and MacGregor (2017), the variation in temperature during cultivation, regardless of the stage of the mother plant, strongly affects the dormancy of the seed produced. Furthermore, these authors reported that the altitude and time of year of cultivation can affect seed dormancy.

In dry chamber storage, the cultivar SCS116 Satoru reached the highest percentage of germination (87%) at 30 days, not differing statistically in the following times. Cultivars Epagri 109, SCS121 CL and SCS122 Miura needed 60 days to reach the highest percentage of germination. While the cultivar SCSBRS Tio Taka required approximately 120 days of storage (Figure 1A).

It is possible to observe that the cultivars had different storage performance. Seed lots may respond differently to environmental effects, especially when they come from different production conditions (CATÃO *et al*., 2018), as occurred in this study. All these factors can influence the dormancy and physiological quality of the seeds produced.

It was observed that SCSBRS Tio Taka, SCS116 Satoru, SCS121 CL and SCS122 Miura cultivars presented higher percentage of dormancy and obtained a significant reduction in the number of dormant seeds after 30 days of storage in a dry chamber. However, the cultivar Epagri 109, with a lower percentage of dormant seeds at harvest (14%), required more time for a significant reduction to occur (Figure 1B).

Figure 1 - Germination and dormancy, regression equations and coefficients of determinations obtained for the effect of time and the storage condition of seeds of rice cultivars in the 2016/17 season



Symbols indicate significant differences by the tukey test ($p < 0.05$): ~ storage factor; ^ time factor; * cultivar factor. Their combination indicates the interaction that was significant. (A) Germination - Regression equations and coefficients of determinations - DRY CHAMBER: Epagri 109 $y = -0.0013x^2 + 0.2669x + 78.161^*$ $R^2 = 0.77$; SCS116 Satoru $y = -0.0022x^2 + 0.381x + 76.892^*$ $R^2 = 0.99$; SCSBRS Tio Taka $y = -0.0034x^2 + 0.5853x + 62.867^*$ $R^2 = 0.93$; SCS121 CL $y = -0.0049x^2 + 0.813x + 59.08^*$ $R^2 = 0.98$; SCS122 Miura $y = -0.0044x^2 + 0.8726x + 43.371^*$ $R^2 = 0.99$. CONVENTIONAL STORAGE: Epagri 109 $y = 0.0006x^2 + 0.0485x + 78.826^*$ $R^2 = 0.92$; SCS116 Satoru $y = -0.0023x^2 + 0.5431x + 53.415^*$ $R^2 = 0.99$; SCSBRS Tio Taka $y = -0.0019x^2 + 0.4566x + 61.644^*$ $R^2 = 0.99$; SCS121 CL $y = 6E\text{-}05x^2 + 0.2659x + 56.942^*$ $R^2 = 0.97$; SCS122 Miura $y = -0.0005x^2 + 0.4089x + 42.865^*$ $R^2 = 0.98$. * Significant by T-test ($p < 0.05$). (B) Dormancy - Regression equations and coefficients of determinations - DRY CHAMBER: Epagri 109 $y = -0.002x^2 + 0.543x + 36.992^{ns}$ $R^2 = 0.99$; SCS116 Satoru $y = 0.0023x^2 + 0.0561x + 30.261^{ns}$ $R^2 = 0.99$; SCSBRS Tio Taka $y = 0.0017x^2 + 0.0247x + 29.801^{ns}$ $R^2 = 0.99$; SCS121 CL $y = -7E\text{-}05x^3 + 0.0162x^2 - 1.2324x + 30.9^{ns}$ $R^2 = 0.99$; SCS122 Miura $y = -0.0009x^2 + 0.5783x + 27.126^{ns}$ $R^2 = 0.99$. CONVENTIONAL STORAGE: Epagri 109 $y = 3E\text{-}05x^3 - 0.0045x^2 + 0.0747x + 13.625^{ns}$ $R^2 = 0.99$; SCS116 Satoru $y = -6E\text{-}05x^3 + 0.0129x^2 - 0.9913x + 39.125^{ns}$ $R^2 = 0.99$; SCSBRS Tio Taka $y = -3E\text{-}06x^3 + 0.002x^2 - 0.4174x + 27.667^{ns}$ $R^2 = 0.99$; SCS121 CL $y = 4E\text{-}05x^3 - 0.0062x^2 - 0.0567x + 30.9^{ns}$ $R^2 = 0.99$; SCS122 Miura $y = 5E\text{-}05x^3 - 0.0085x^2 - 0.0427x + 41.75^{ns}$ $R^2 = 0.99$. * Significant by T-test ($p < 0.05$)

In conventional storage, cultivar SCS116 Satoru took 60 days to reach the highest percentage of germination (77%), while the other cultivars needed 120 days, possibly due to the higher percentage of dormant seeds. Unlike what was observed in the dry chamber, in this storage condition, cultivars with the highest percentage of dormancy required more time to significantly reduce dormancy.

At 30 and 60 days of storage in a dry chamber, cultivars SCS116 Satoru, SCS121 CL and SCS122 Miura showed a lower percentage of dormant seeds than in conventional storage (Figure 1B). Similar to Menezes *et al.* (2013) who also observed that at 60 days of storage (25 ºC and RH 40%) there were no more dormant seeds in different rice genotypes.

The overcoming of dormancy in rice seeds can occur due to the oxidation of germination inhibitors, by the action of oxygen present in the environment, and by the temperature of the storage place (VIEIRA *et al*., 2002).

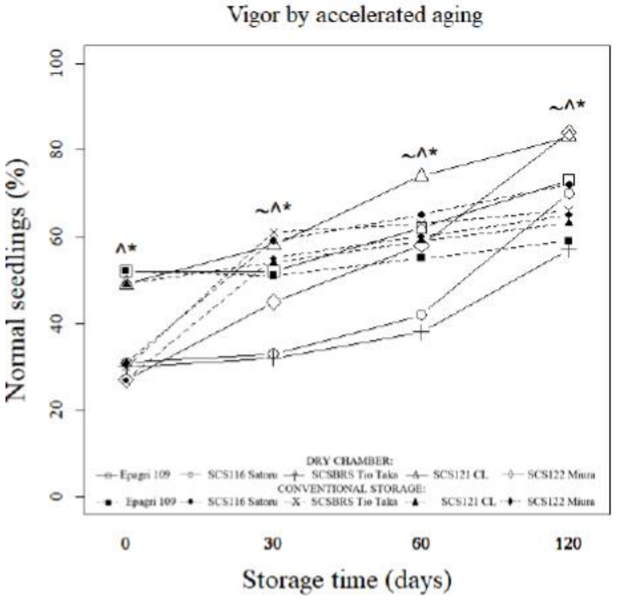
At 120 days, there was no statistical difference in germination between storage conditions, so it can be seen that the environmental conditions did not significantly affect germination (Figure 1A).

In relation to vigor by accelerated aging, it was observed that the cultivars Epagri 109 and SCS121 CL after harvest, presented percentage significantly higher than the others, with 52 and 49%, respectively (Figure 2).

When stored in a dry chamber, the cultivars required approximately 120 days to reach the maximum percentage of vigor of the evaluated periods (Figure 2). The cultivars SCS121 CL and SCS122 Miura showed the highest vigor percentages (83 and 84%, respectively), while the cultivar SCSBRS Tio Taka the lowest (57%) in this condition (Figure 2).

In conventional storage, it was observed that most cultivars reached maximum percentage of vigor after 30 days of storage, not differing significantly in the following times. At the end of this storage condition, there was no statistical difference between cultivars (Figure 2).

Figure 2 - Vigor by accelerated aging, regression equations and coefficients of determinations obtained for the effect of time and the storage condition of the seeds of rice cultivars in the 2016/17 season



Symbols indicate significant differences by Tukey test ($p < 0.05$): ~ Storage factor; ^ Time factor; *cultivar factor. Their combination indicates the interaction that was significant. Regression equations and coefficients of determinations - DRY CHAMBER: Epagri 109 $y = -0.002x^2 + 0.543x + 36.992^*$ $R^2 = 0.99$; SCS116 Satoru $y = 0.0023x^2 + 0.0561x + 30.261^*$ $R^2 = 0.99$; SCSBRS Tio Taka $y = 0.0017x^2 + 0.0247x + 29.801^{ns}$ $R^2 = 0.99$; SCS121 CL $y = -0.0049x^2 + 0.813x + 59.080^*$ $R^2 = 0.98$; SCS122 Miura $y = -0.0009x^2 + 0.5783x + 27.126^*$ $R^2 = 0.99$. CONVENTIONAL STORAGE: Epagri 109 $y = 0.0004x^2 + 0.0194x + 51.600^*$ $R^2 = 0.93$; SCS116 Satoru $y = -0.0054x^2 + 0.9163x + 32.189^*$ $R^2 = 0.93$; SCSBRS Tio Taka $y = -0.0054x^2 + 0.9163x + 32.189^*$ $R^2 = 0.93$; SCS121 CL $y = -0.0008x^2 + 0.2094x + 48.836^*$ $R^2 = 0.99$; SCS122 Miura $y = -0.0054x^2 + 0.9163x + 32.189^*$ $R^2 = 0.93$.* Significant by T-test ($p < 0.05$)

However, there was statistical difference for vigor between conditions at 120 days of storage. In the conventional, there was a lower mean percentage of vigor. It is possible that because this condition requires more time to overcome dormancy, this has delayed the expression of physiological potential.

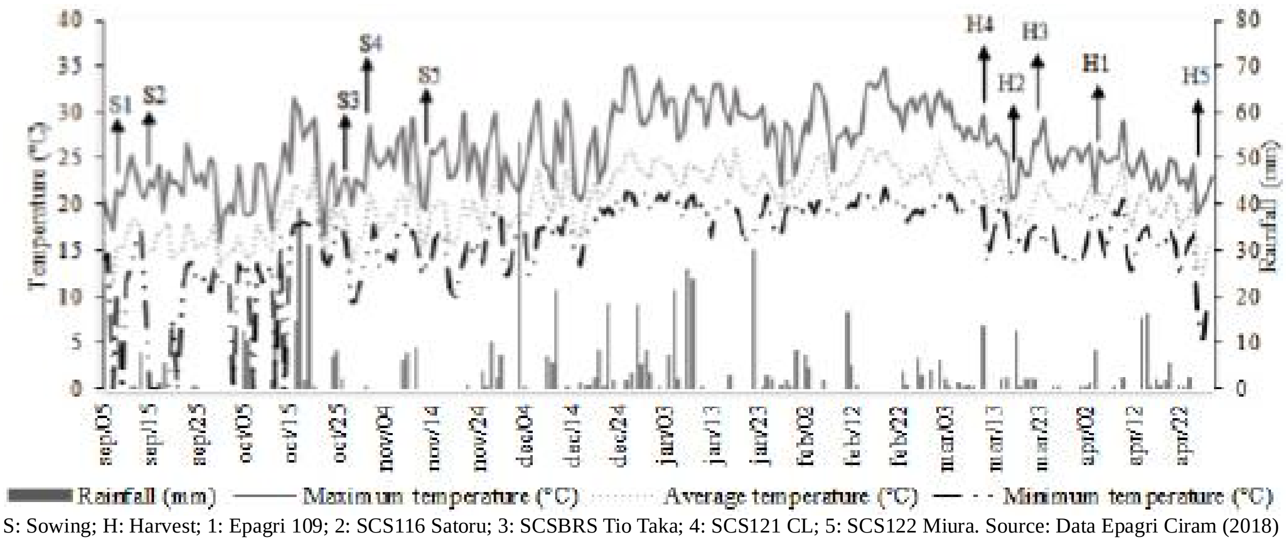
Analyzing the climatic conditions that occurred along the production cycle of the seeds of the tested cultivars (Figure 3), it was observed that the lots that presented higher dormancy, suffered great temperature fluctuation and significant volumes of precipitation near the harvest. Showing that environmental conditions are predominant in inducing dormancy in seeds of the species, especially in the field maturation phase.

Furthermore, it is noteworthy that after harvesting, seed storage conditions are also crucial for maintaining the quality of seeds produced in the field. During storage, the temperature and relative humidity of the air to which the seeds are subjected are two extremely important factors for maintaining the physiological quality (COSTA, 2012).

Each decrease of 5.6 ºC in storage temperature can double the viability period (COSTA, 2012; LABBÉ; VILLELA; PESKE, 2019). In conventional storage. temperatures fluctuated between 7 and 20 °C, while in the dry chamber, the temperature remained at 10 °C (Figure 4). Thus, the increase in temperature that occurred during conventional storage may have caused a reduction in seed viability.

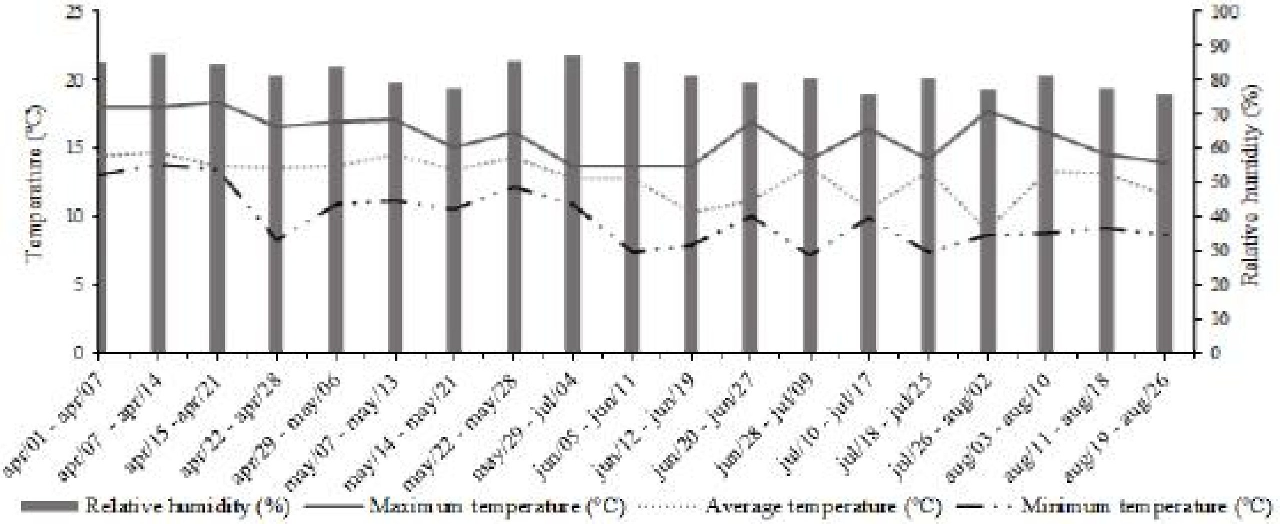
Air relative humidity is also important in maintaining the physiological quality of seeds. A low percentage of moisture induces a reduction in metabolic activity, enabling the maintenance of physiological

Figure 3 - Rainfall (mm), maximum, average and minimum air temperature (°C) that occurred from sowing to harvesting rice seed lots in the 2016/17 crop in the Alto Vale do Itajaí, SC



S: Sowing; H: Harvest; 1: Epagri 109; 2: SCS116 Satoru; 3: SCSBRS Tio Taka; 4: SCS121 CL; 5: SCS122 Miura. Source: Data Epagri Ciram (2018)

Figure 4 - Relative humidity (%) and maximum, average and minimum temperature (°C) during conventional storage in Rio do Sul, SC, of rice seeds produced in the 2016/17 season



Source: Data collected by authors

quality for a longer period due to low deterioration (CARDOSO; BINOTTI; CARDOSO, 2012).

The storage conditions tested had air humidity ranging from 75 to 90% in conventional storage (Figure 3), and 50% constant in the dry chamber (Figure 4). With the deterioration process, this change can make the seed more sensitive to stress. Furthermore, fluctuations in air temperature and humidity can affect the seed membrane system and, consequently, lead to the reduction of normal seedlings.

According to Zucarelli *et al.* (2015), the reduction of physiological quality may occur due to the initial process of seed deterioration, which when exposed to temperature and humidity fluctuations become more susceptible to stresses during germination.

In addition, the periods with occurrence of the highest temperatures recorded in conventional storage demonstrated not to have been sufficient to promote faster breaking of dormancy (Figure 3). This is possibly due to the temperature fluctuations that have occurred.

In the 2017/18 season, the cultivars Epagri 109 and Primoriso CL showed the highest percentage of germination at 25 °C after harvest, 80 and 79%, respectively, differing statistically from the other cultivars. While the SCS121 CL and SCS122 Miura cultivars had the lowest percentage, 73 and 72%, respectively (Figure 5A).

When stored in a dry chamber, the cultivars SCS121 CL, SCS122 Miura and Primoriso CL needed 60 days to reach maximum germination between the times evaluated. Cultivar Primoriso CL had significantly higher germination than conventional storage at times of 30, 60, 90 and 120 days (Figure 5A).

In conventional storage, the cultivars Epagri 109, SCS121 CL and Primoriso CL showed no significant differences between times. Only cultivar SCS122 Miura differed, reaching the maximum percentage of germination (87%) at 30 days (Figure 5A).

In general, it was observed that in this season, for most cultivars, except for SCS122 Miura, there were no differences between the storage conditions and the percentage of dormancy during storage (Figure 5B). Possibly due to the lower percentage of dormant seeds after harvest.

In dry chamber storage, the cultivars Epagri 109 and Primoriso CL had significantly reduced dormancy at 30 days, while the others needed 60 days (Figure 5B).

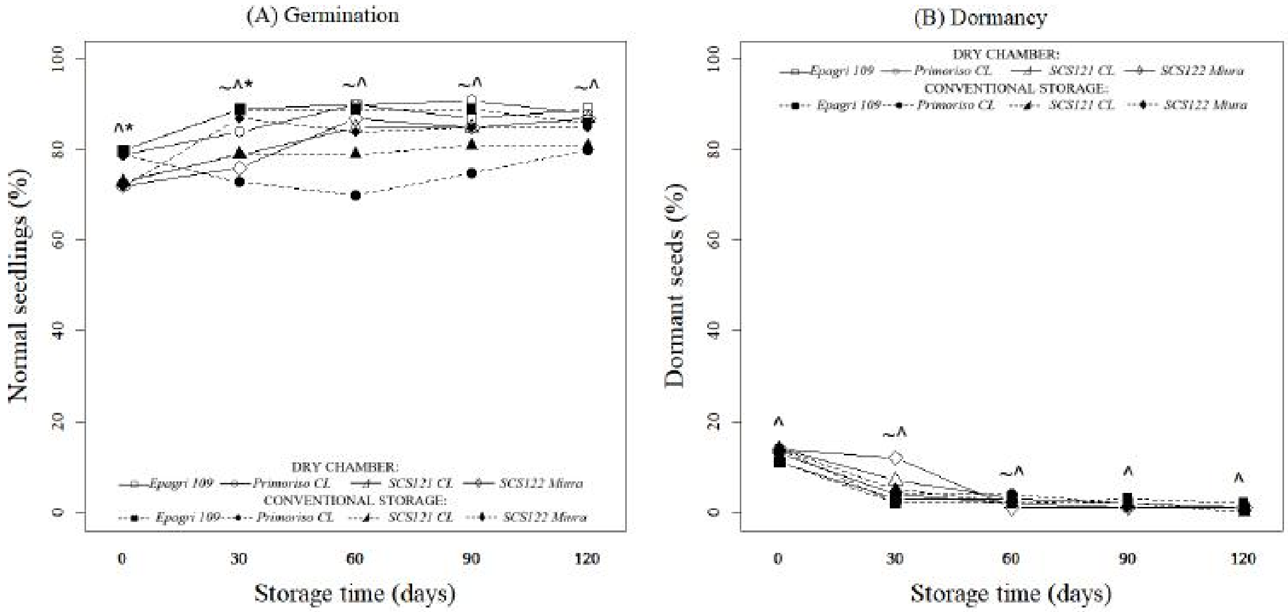
Similar to what was observed by Marques *et al.* (2014) who found differences in the performance of rice cultivars in overcoming dormancy, and cultivar Seleta was not influenced by the temperature of the environment in relation to the time needed to overcome dormancy.

When stored in the conventional system, all cultivars at 30 days had significantly reduced dormancy (Figure 5B).

In dry chamber, the cultivar Primoriso CL reached maximum vigor (89%) after 30 days, while the cultivars Epagri 109 and SCS121 CL demanded for 60 days (73 and 88%) and the SCS122 Miura 90 days (69%) (Figure 6).

At the end of storage at 120 days, the cultivars SCS121 CL (87%) and Primoriso CL (92%) stood

Figure 5 - Germination and dormancy, regression equations and coefficients of determinations obtained for the effect of time and the storage condition of seeds of rice cultivars in the 2017/18 season



Symbols indicate significant differences by the tukey test ($p < 0.05$): ~ storage factor; ^ time factor; * cultivar factor. Their combination indicates the interaction that was significant. (A) Germination - Regression equations and coefficients of determinations - DRY CHAMBER - Epagri 109 $y = 4E\text{-}05x^3 - 0.0088x^2 + 0.5406x + 79.662^*$ $R^2 = 0.99$; Primoriso CL $y = -0.0026x^2 + 0.356x + 78.816^*$ $R^2 = 0.98$; SCS121 CL $y = -0.0009x^2 + 0.2195x + 73.62^*$ $R^2 = 0.97$; SCS122 Miura $y = -0.0013x^2 + 0.2815x + 71.471^*$ $R^2 = 0.86$. CONVENTIONAL STORAGE - Epagri 109 $y = 2E\text{-}05x^3 - 0.0052x^2 + 0.4114x + 79.916^*$ $R^2 = 0.97$; Primoriso CL $y = -8E\text{-}06x^3 + 0.0036x^2 - 0.3173x + 78.874^*$ $R^2 = 0.96$; SCS121 CL $y = 1E\text{-}05x^3 - 0.0032x^2 + 0.2394x + 73.631^*$ $R^2 = 0.93$; SCS122 Miura $y = 5E\text{-}05x^3 - 0.011x^2 + 0.707x + 72.748^*$ $R^2 = 0.93$. (B) Dormancy - Regression equations and coefficients of determinations - DRY CHAMBER - Epagri 109 $y = -2E\text{-}05x^3 + 0.0047x^2 - 0.3432x + 10.355^{ns}$ $R^2 = 0.97$; Primoriso CL $y = 0.001x^2 - 0.2239x + 12.821^{ns}$ $R^2 = 0.99$; SCS121 CL $y = 3E\text{-}05x^3 - 0.0042x^2 + 0.0094x + 14.435^{ns}$ $R^2 = 0.97$; SCS122 Miura $y = 0.0012x^2 - 0.2718x + 15.321^{ns}$ $R^2 = 0.89$. CONVENTIONAL STORAGE - Epagri 109 $y = -2E\text{-}05x^3 + 0.0054x^2 - 0.3942x + 10.368^{ns}$ $R^2 = 0.98$; Primoriso CL $y = -1E\text{-}05x^3 + 0.0039x^2 - 0.3523x + 12.582^{ns}$ $R^2 = 0.93$; SCS121 CL $y = 0.0015x^2 - 0.282x + 13.498^{ns}$ $R^2 = 0.96$; SCS122 Miura $y = -3E\text{-}05x^3 + 0.0081x^2 - 0.5857x + 13.786^{ns}$ $R^2 = 0.98$. * Significant by T-test ($p < 0.05$)

out for their greater vigor and SCS122 Miura for the lowest percentage (76%) (Figure 6). This performance demonstrates the variation that exists in the physiological quality of rice seeds after harvest. This variation is mainly related to the genotype and the degree of seed dormancy.

In conventional storage, it was observed that the cultivar Epagri 109 reached the highest percentage of vigor (82%) after 30 days, while the others needed 60 days (Table 6). At 120 days, only the cultivar Primoriso CL differed statistically between the storage conditions, showing the highest percentage when stored in a dry chamber (83%) (Figure 6).

Lima *et al.* (2019) also observed that because rice presents dormancy after harvest, during storage there is an increase in the physiological quality of the seeds.

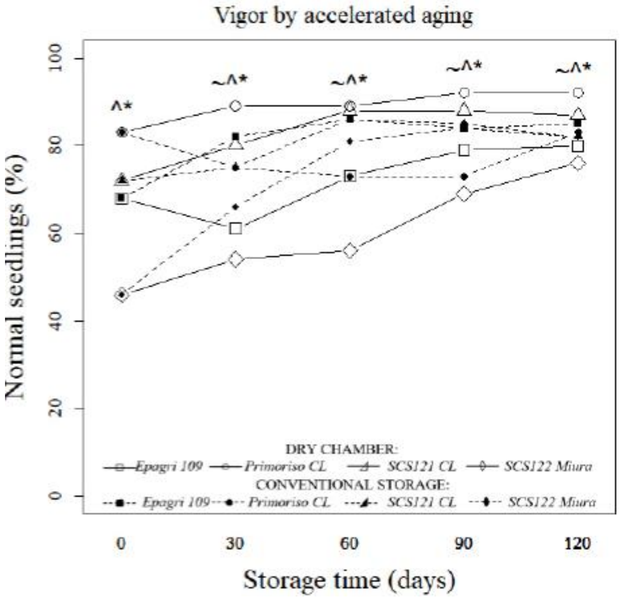
Analyzing the climatic data of seed production for the 2017/18 season, it was observed that there was less variation in temperature throughout the cycle and that during the maturation phase there was a lower volume of precipitation (Figure 7). Considering that there was a lower percentage of dormant seeds and compared with the previous harvest, this result corroborates the hypothesis raised in this study, that large temperature fluctuations throughout the production cycle and high volumes of precipitation in maturation can induce dormancy in rice seeds.

Under the storage conditions, the temperatures ranged from 6 to 20 °C, in the conventional one, and remained at 10 °C in the dry chamber (Figure 8). Presenting a profile of environmental conditions very similar to that seen in the previous season.

It is important to emphasize the temperature fluctuations that occurred in conventional storage. As well as the relative humidity of the air, which remained high, from 78 to 90%, while in the dry chamber the humidity remained at 50% (Figure 8).

Because seeds are hygroscopic, when stored in environments without temperature and humidity control, they have a higher water content than those stored in a dry chamber (ZUCARELLI *et al.*, 2015). With this increase in water content, the respiratory process is accentuated, and the seed deterioration process accelerates, resulting in a reduction in physiological quality.

Figure 6 - Vigor by accelerated aging, regression equations and coefficients of determination obtained for the effect of time and the storage condition of the seeds of rice cultivars in the 2017/18 season



Symbols indicate significant differences by the tukey test ($p < 0.05$): ~ storage factor; ^ Time factor; * Cultivar factor. Their combination indicates the interaction that was significant. Regression equations and coefficients of determinations - DRY CHAMBER - Epagri 109 $y = -7E\text{-}05x^3 + 0.0139x^2 - 0.5246x + 68.01^*$ $R^2 = 0.96$; Primoriso CL $y = -0.0008x^2 + 0.1676x + 83.163^*$ $R^2 = 0.94$; SCS121 CL $y = -0.0021x^2 + 0.3823x + 71.181^*$ $R^2 = 0.98$; SCS122 Miura $y = 0.0007x^2 + 0.1566x + 46.598^*$ $R^2 = 0.97$. CONVENTIONAL STORAGE - Epagri 109 $y = 4E\text{-}05x^3 - 0.0102x^2 + 0.7327x + 68.321^*$ $R^2 = 0.99$; Primoriso CL $y = 7E\text{-}05x^3 - 0.0118x^2 + 0.5802x + 67.251^*$ $R^2 = 0.99$; SCS121 CL $y = -3E\text{-}05x^3 + 0.0034x^2 + 0.1092x + 71.145^*$ $R^2 = 0.93$; SCS122 Miura $y = -2E\text{-}05x^3 + 0.0008x^2 + 0.4492x + 53.378^*$ $R^2 = 0.99$. * Significant by T-test ($p < 0.05$)

In both harvests, it was verified that there was no reduction in the physiological quality of the seeds in the storage conditions evaluated. On the contrary, an increase in germination and vigor was observed up to 120 days. This is due to the dormancy present in the seeds, as the maximum germination and vigor of rice seeds may correspond to the moment when dormancy is overcome (MARQUES *et al*., 2014).

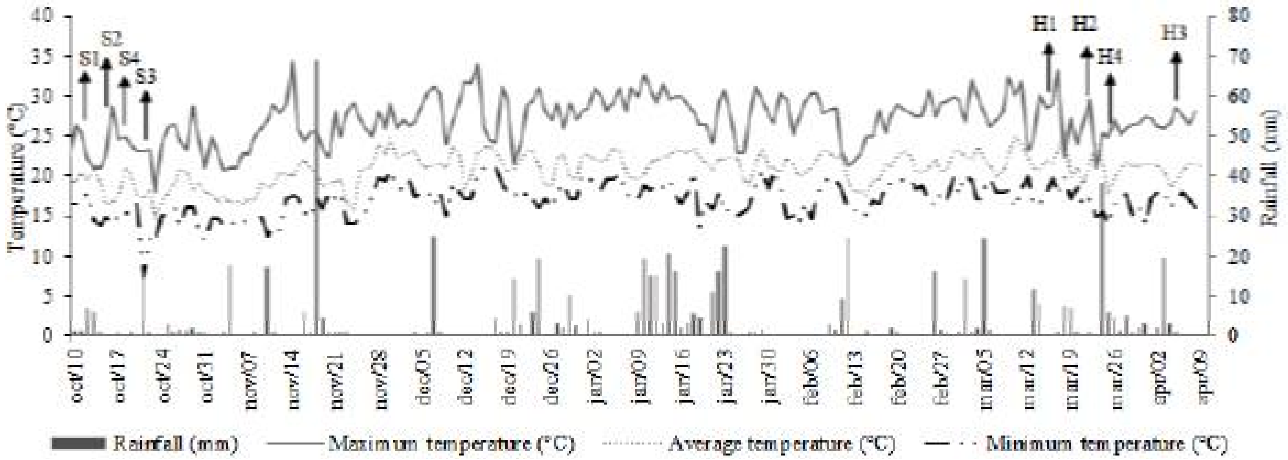
The dormancy of rice seeds varies between cultivars (LIMA *et al*., 2019) and the intensity may vary according to the genotype and environmental conditions during maturation and storage (MENEZES *et al*., 2013). In this study, it was observed that the cultivars SCS122 Miura, SCSBRS Tio Taka and SCS116 Satoru presented the highest percentage of dormant seeds, about 30%.

In addition, a distinct dormancy response was observed in the face of storage conditions. Vieira *et al*. (2002) also concluded that overcoming dormancy is affected by storage conditions.

According to Bewley *et al*. (2013) the rise in temperature during the storage of rice seeds can reduce dormancy. However, conventional storage, which had a very similar profile of environmental conditions in both crops, with higher temperatures, did not favor breaking dormancy. This is possibly due to the large fluctuations in temperature (6 to 20 °C) and relative humidity that have occurred.

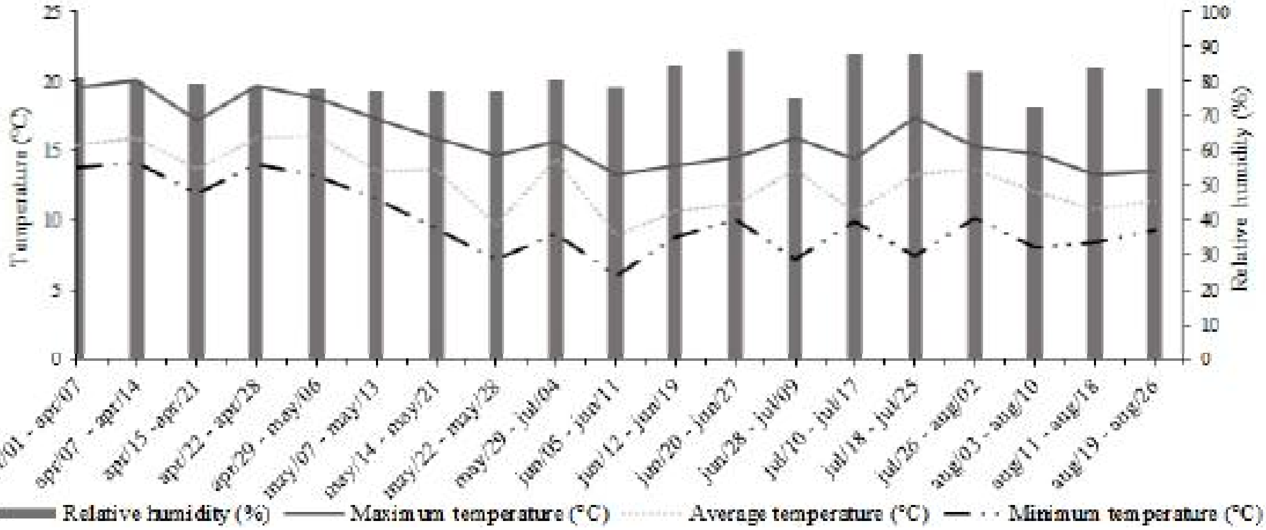
Temperature is an important factor for seed conservation, directly affecting the speed of biochemical processes and indirectly interfering with the moisture

Figure 7 - Rainfall (mm) and maximum. average and minimum air temperature (°C) occurring from sowing to harvest of rice seed lots in the 2017/18 season in Alto Vale do Itajaí. SC



S: Sowing; H: Harvest; 1: Epagri 109; 2: SCS121 CL; 3: SCS122 Miura; 4: Primoriso CL. Source: Epagri Ciram Database (2018)

Figure 8 - Data of relative humidity (%) and maximum, average and minimum temperature (°C) during conventional storage in Rio do Sul, SC, of rice seeds produced in the 2017/18 season



Source: Data collected by authors

content, resulting in other processes, such as increased enzymatic activities (hydrolytic enzymes) and free fatty acids (MARQUES *et al*., 2014).

Furthermore, the fluctuation of the relative humidity of the air can favor the loss of viability more quickly than seeds stored under constant humidity conditions (BARTON, 1961). Silva *et al.* (2014) pointed out that when exposed to fluctuations in temperature and humidity, seeds lose their physiological quality more quickly and reduce their ability to produce normal seedlings.

In the 2016/17 season, which had a higher percentage of dormant seeds, the dry chamber was more efficient in overcoming seed dormancy. Unlike what was observed by Vieira *et al.* (2008) where rice seeds stored in conventional environments in the cities of Lavras and Patos de Minas in Minas Gerais, overcame dormancy faster than seeds stored in a dry chamber (10 °C and 50% RH). According to the author, the conventional environment presented higher temperatures (13-33 °C and 53-82% RH) and consequently promoted the overcoming of dormancy.

Dormancy in rice seeds at sowing time is usually not a problem. However, as observed in this work, the seeds can take up to 60 days to overcome this dormancy. Not coinciding with the sowing season. However, it is considered a hindrance in the laboratory analysis of its quality, which is performed immediately after harvest, an important moment for decision-making on the use of the lot. Because the efficiency of the overcoming methods depends on the intensity of the dormancy presented by these seeds.

In general, it was observed that the dry chamber brought about the overcoming of dormancy and expression of the physiological quality of the seed throughout storage, where the stability of climatic conditions may have been determinant. Similar to that found in this study, Marques *et al.* (2014) observed that overall, rice seeds stored at temperatures of 5, 12 and 18 °C presented higher physiological quality than seeds stored under ambient conditions (15-38 °C and 40-80% RH). Smiderle and Dias (2011) in the study of the time of harvesting and environmental storage (RH 65 ± 5% and 20 ± 5 ºC) of rice seeds produced in the cerrado of Roraima, concluded that seeds of this species in plastic bags can maintain physiological quality under these conditions for twelve months. Similarly, Park *et al*. (2012) also found that storage at low temperatures (4 °C) is recommended to maintain the physicochemical qualities of rice.

In addition, it was observed that the cultivars Epagri 109 and SCS121 CL used in both crops, and primoriso CL used in the 2017/18 crop had results higher than 80% germination at 25 ºC, showed high physiological quality and demonstrated a good storage potential.

CONCLUSIONS

1. The conditions of temperature and humidity in storage affect the overcoming of rice seeds dormancy;
2. The dry chamber (10 ºC and 50% RH) favors the overcoming of dormancy and the maintenance of the

physiological quality of the seeds of rice cultivars Epagri 109, SCS121 CL, SCS122 Miura and Primoriso CL, when compared to conventional storage.

ACKNOWLEDGEMENTS

We acknowledge the financial support received from CAPES-BRASIL. Also thanks to the Cooperativa Regional Agropecuária Vale do Itajaí for the donation of seeds and for the partnership in this work. The second author thanks FAPESC-UDESC-PAP for the financial assistance in processing the articles and CNPq for the Research Productivity Scholarships.

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