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RESEARCH NOTE

Intermittence periods in corn seed drying process[1]

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ABSTRACT - The high quality is a factor that must be assured in a corn seed production system. In order to achieve this, seeds are harvested with high moisture content, and then artificially dried. However, the costs of this operation are high and may reduce the profits. The objective of the present study was to evaluate, through the physiological quality, the possibility of using intermittence periods for drying corn seeds on the cob in a stationary system. The seeds were harvested on the cob, close to the physiological maturity stage, with an average moisture content of 35%. The treatments consisted of four periods of intermittence (3, 6 and 9 hours) and one period without intermittence. The seeds were stored for six months. To evaluate the physiological quality of the seeds, germination, first germination, electrical conductivity, and the cold tests were performed. The experimental design was completely randomized, in split plots. In a stationary drying system, periods of intermittence of up to 6 hours per day helped to preserve the physiological quality of the corn seeds. The use of intermittence periods in the drying process provides corn seeds with higher physiological quality and greater storage potential, in comparison with the continuous drying.

Index terms: physiological quality, intermittent drying, *Zea mays* L.

Períodos de intermitência na secagem de sementes de milho

RESUMO - Na produção de sementes de milho, a alta qualidade é um fator primordial. Nesse sentido, as sementes são colhidas com elevado teor de água e posteriormente secas artificialmente. Entretanto, o custo desta operação é elevado, o que a torna um limitante da lucratividade. O objetivo do presente trabalho foi avaliar, por meio da qualidade fisiológica, a possibilidade de utilização de períodos de intermitência na secagem de sementes de milho em espiga, em um sistema de secagem estacionário. As sementes foram colhidas em espiga, próximo ao ponto de maturidade fisiológica, com teor de água médio de 35%. Os tratamentos constaram de quatro períodos de intermitência (3, 6 e 9 horas) e um período sem intermitência. As sementes foram armazenadas durante seis meses. Para avaliação da qualidade fisiológica das sementes, foram realizados os testes de germinação, primeira contagem de germinação, teste de frio e condutividade elétrica. O delineamento experimental empregado foi inteiramente ao acaso, em parcelas subdivididas. No sistema de secagem estacionário, períodos de intermitência de até 6 horas por dia na secagem de sementes de milho em espiga preservaram a qualidade fisiológica das sementes. A utilização de períodos de intermitência na secagem de sementes de milho proporciona sementes de maior qualidade fisiológica e maior potencial de armazenamento, em relação à secagem continua.

Termos para indexação: qualidade fisiológica, secagem intermitente, *Zea mays* L.

Introduction

Corn (*Zea mays* L.) is a crop with one of the largest production areas in Brazil, and it is cultivated in most of the producer states of the country. The 2015/2016 crop year presented a cultivated area of 15,466.6 thousand hectares, reaching an average productivity of 5,4 t.ha^{-1} (Conab, 2016). The culture shows a rate of certified seed use of 90%, which

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is one of the highest in the country.

In addition to its socioeconomic importance, as it is one of the most important food sources for the population, corn stands out in seed industry due to the considerable cultivated area and to the high seed use rate. So, it is one of the main crops of interest in this sector.

In Brazil, corn seed production is characterized by the high quality of its products. This can be partially attributed to the seed harvest timing, which occurs close to the physiological maturity stage, minimizing the deleterious effect of field storage. However, this practice must be followed by artificial drying in order to prevent the beginning of deterioration process, marked by an increase of respiratory activity and consumption of the reserves (Peske and Villela, 2012).

As a result of drying, the reduction in seed moisture content causes a decrease in metabolic activity. This contributes to slow down the deterioration and to increase storage time, without significantly reducing the physiological quality (Marcos-Filho, 2005; Santos et al., 2013).

Currently, corn seeds are dried on the cobs in fixed bed dryers (stationary), using a continuous drying process, due to the high moisture content of the seeds at harvest. However, the high electricity cost, especially at peak hours, makes the operation costly for Brazilian seed companies. So, the adaptation of the existing process by introducing intermittence periods during the drying phase can result in financial savings for the corn seed production system.

Intermittent drying is characterized by the exposure of the seed mass to a hot air flow for a certain time, followed by a period without the air flow (Guimarães et al., 2015). The intermittence period allows the migration of water from the interior to the periphery of the seeds, thus reducing hydric and thermal gradients (Villela and Peske, 1997).

The objective of the present study was to evaluate the possibility of using intermittence periods for drying corn seeds on the cob in a stationary system, as a technique to preserve seed quality and reduce operational costs.

Material and Methods

The experiment was performed at the Laboratory of Seed Analysis, associated with the Postgraduate Program in Seed Science and Technology, and at the Post-Harvest Laboratory of the Engineer Center, both located at the *Universidade Federal de Pelotas*.

Seeds were harvested on the cob, close to the physiological maturity stage, with 35% moisture content. The formation of kernel black layer, an indicator widely used, was considered to establish the harvest time.

After the harvest, the cobs had the straw removed and were sent to a metallic stationary dryer with a perforated false bottom. Subsequently, the seeds on the cob were submitted to the treatments.

The treatments included three intermittence periods (3, 6 and 9 hours) and one without intermittence (continuous drying). The temperature of the air used for drying was 40 ºC, which was not exceeded in the seed mass. The drying air flow rate ranged from 4 to 6 $m^3.min^{-1}.t^{-1}$.

During drying, the moisture content of the seed mass was monitored. To do so, samples were collected every 6 hours , and then analyzed by the oven method at 105 ºC, according to methodology of Brasil (2009). Thus, from the resulting data, the drying curves of the processes using different intermittence period were drawn.

After drying up to about 10% moisture, the corn cobs were threshed, and the seeds were packed in paper bags and maintained in storage environment at 10 ºC and 50% relative humidity, simulating the most common storage conditions used by corn seed producers.

The seeds were stored for six months. This period allowed to detect latent damage resulting from the treatments. To evaluate the physiological quality of the seeds, samples were collected every 30 days, with the first sampling performed at the beginning of storage.

To assess the physiological quality of the seeds, the following tests were carried out.

Germination: 200 seeds per sample (divided into 8 subsamples of 25 seeds) were sowed in paper rolls moistened with distilled water in the ratio of 2.5 times the dry substrate mass. Then, they were kept in germinator at 25 ºC. The count was performed seven days after the test was set up (Brasil, 2009).

First germination count: it was carried out together with the germination test, and the count was performed four days after sowing (Brasil, 2009).

Cold test: it was performed according to Cícero and Vieira (1994), with four replications of 50 seeds. They were placed on paper rolls moistened with distilled water in the ratio of 2.5 times the dry paper mass. After sowing, the rolls were packed in plastic bags, sealed with adhesive tape and maintained inside cold chamber at 10 ºC for 7 days. After this period, the rolls were taken from the plastic bags and transferred to a germinator at 25 ºC, where they were kept for 4 days. The normal seedling count was performed on the 4^{th} day (Brasil, 2009).

Electrical conductivity: the seeds were weighed to two decimal places precision. Later on, they were put in plastic cups with 75 mL of distilled water and maintained in a germinator at a constant temperature of 25 °C. After 24 hours of imbibition, the electrical conductivity of the solution was determined with a conductivity meter (DIGIMED - DM 31), as described by Vieira and Krzyzanowski (1999).

The experimental design was completely randomized, in split plots 4x6 (4 intermittence periods and 6 evaluation periods). Analysis of variance was performed on data and, in case of significance at 5% probability, they were submitted to polynomial regression analysis.

Results and Discussion

Drying corn seeds (35% initial moisture content) in a fixed bed requires about 84 to 120 hours, but it can take up to 144 hours, depending on the characteristics of the hybrid (Seibt et al., 2013), and of the air flow. However, the high cost makes drying the second most expensive process, due to the high energy consumption, both in the form of gas and also electricity (Gent et al., 2012). Hence, the use of intermittence periods minimizes the operational cost, because it allows the interruption of the system without compromising the water removal and the quality of seeds.

The variable first germination count (Figure 1A) presented a cubic behavior, with R^2=99.8. The response of the first germination count increased up to the 6th hour of intermittence period. However, longer periods resulted in a decrease in quality. In this case, the best performance was obtained with the intermittence period of 6 hours. Periods of 4 and 5 hours also favored the performance of the first germination count (Figure 1A).

As for the variable germination (Figure 1B), a trend similar to the first germination count (cubic curve, R^2 = 98.9) was observed, with higher germination values for the 6-hour interruption. From the result obtained in the present study, it is possible to recommend the use of intermittence periods from 5 to 7 hours.

It is worth mentioning that, for the first germination count (Figure 1A) and germination (Figure 1B), the use of up to 6 hours of intermittence offered increments in relation to the continuous drying (without intermittence), thus providing greater seed quality after drying.

In the cold test (Figure 1C), a decreasing quadratic trend

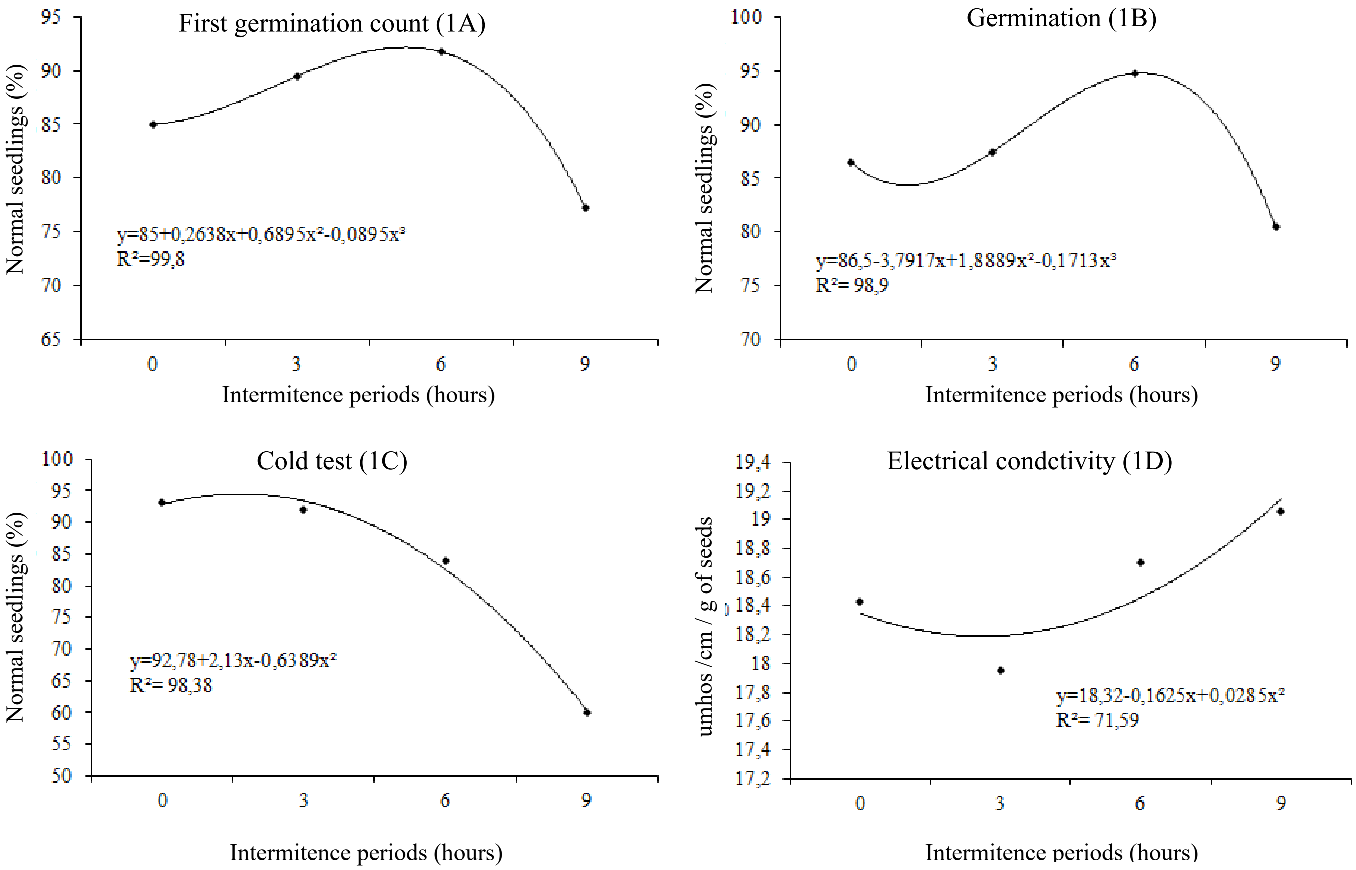

Figure 1. Result curves for first germination count (1A), germination (1B), cold test (1C), and electrical conductivity (1D) in corn seeds submitted to intermittence periods during drying.

was observed (R^2 = 88.38). Therefore, as the intermittence period during drying augmented, the vigor assessed by the cold test reduced. The trend curve evidenced that periods of up to 3 hours of intermittence did not significantly affected the initial performance of the seeds.

The electrical conductivity analysis of the treatments (Figure 1D) presented a growing quadratic response (R^2 = 85.27). This indicates that increasing the intermittence periods caused damage to the cell membranes, which was evidenced by the greater leaching of solutes. However, periods of up to 3 hours of intermittence did not compromise seed vigor, according to the conductivity test, similarly to the observed in the cold test (Figure 1A).

The first germination count (Figure 2A) was influenced by the periods of intermittence and storage. It is worth emphasizing that, at the end of the storage, the intermittence period of 9 hours favored the vigor, according to the first germination count.

Regarding the germination performance of the different treatments throughout storage (Figure 2B), it was observed that, at the end of storage, the use of intermittence periods favored germination. A higher performance than that observed in the continuous drying was noticed for all intermittence periods.

In the cold test (Figure 2C), a response similar to that from the first germination count and germination test was obtained, influenced by the intermittence and the storage period together. Until 60 days of storage, the use of continuous drying showed a better performance in the cold test. From that moment on, the use of intermittence periods favored seed performance.

As for the electrical conductivity during the storage period (data not presented), there was no significant effect between the storage periods.

Drying seed with hot air basically involves two simultaneous processes: a) transference (evaporation) of the superficial water of the seed to the surrounding air, which occurs due to a partial vapor pressure gradient between the surface of the seed and the drying air; b) water movement from the inside to the surface of the seed, caused by hydric

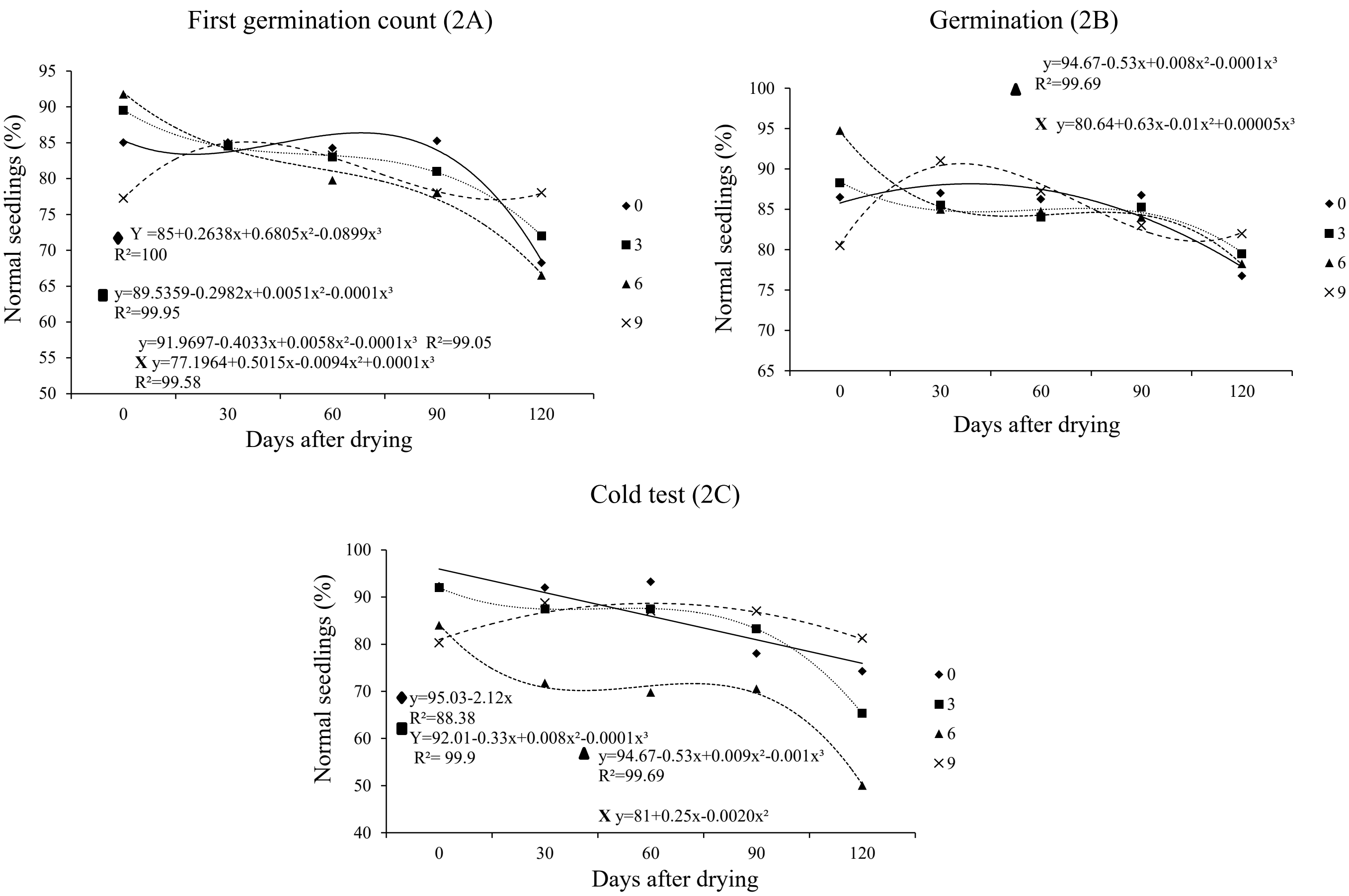

Figure 2. Result curves for first germination count (FGC), germination (G), and cold test (CT) in corn seeds submitted to periods of intermittence during drying, as a function of storage period.

and thermal gradients between these two regions (Peske and Villela, 2012). Since drying is a complex operation that involves simultaneous heat and mass transference phenomena, and taking into account it is based on water migration (Liu et al., 2015), the use of the intermittent method favors such process, in which water migrates from the inside to the surface of the seed, even if the water content in the surface is not excessively low (Peske and Villela, 2012).

Therefore, less damage to the seed may be caused during the drying process. This fact is evidenced in Figures 1 and 2, in which is possible to observe that the use of periods of up to 6 hours of intermittence favored the physiological performance of the seeds. So, this method poses as one of the best alternatives to maintain the quality of seeds obtained from a production field.

In a similar work using drying air at temperatures between 70 °C and 90 °C, Villela and Silva (1991) observed that the use of intermittent drying did not negatively affect the physiological performance of corn seeds. Besides, the authors also verified a reduction in the incidence of *Penicillium* spp. in seeds dried by this method.

The use of intermittence periods in corn seeds drying process tends to cause less latent damage. Seed physiological quality tested during storage (Figure 2) showed that the seeds from treatments that used intermittence periods had a better storage potential. This can be related to a greater damage that seed structure can suffer when it is continuously dried, in comparison with systems with intermittence periods.

The duration of the drying process was not influenced by the use of intermittence periods (Figure 3). In all periods evaluated, all treatments displayed a similar behavior for moisture content (Figure 3). However, in the periods between 48 and 72 hours of drying, not using intermittence provided a greater water removal. Nevertheless, at the end of the total drying period (90 hours), all treatments presented seeds with a moisture content of 10% (± 0.5).

In the initial quality, periods of up to 6 hours of intermittence preserved the physiological quality of seeds (Figures 1A and 1B). As for the physiological quality in the end of storage, in Figure 2 it is possible to observe that a period of up to 9 hours of intermittence resulted in seeds of higher quality.

Considering the high cost of the drying operation, the possibility of using intermittence periods (system shut-off), without compromising the drying rate, and the physiological quality of seeds is an efficient way of making the process less expensive. Thus, it is possible to indicate intermittence periods of up to 6 hours every 24 hours, which could reduce about 25% of costs, if the intermittence period coincided with the peak hours (6-9 p.m.), when the energy is more expensive. It is worth emphasizing, however, that adopting such practice, besides reducing the operational cost, also contributes to the maintenance of the physiological quality of corn seeds.

Conclusions

In a stationary drying system, intermittence periods of up to 6 hours per day preserve the physiological quality of corn seeds.

The use of intermittence periods in corn seed drying provides seeds with higher physiological quality and greater storage potential, compared to the continuous drying process.

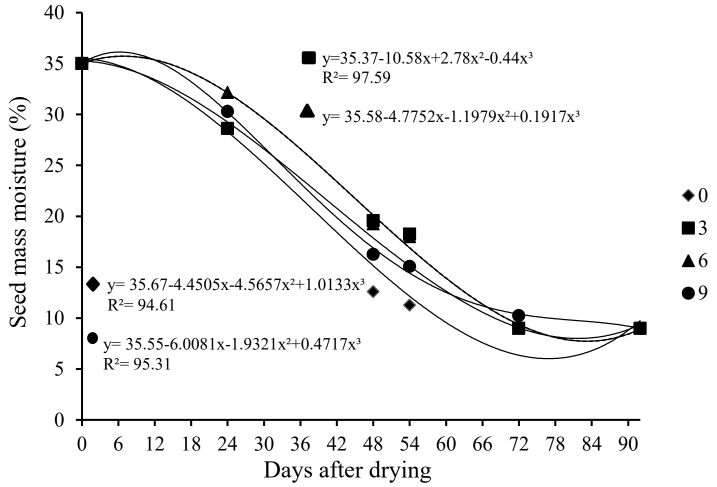

Figure 3. Drying curves for corn seeds submitted to different periods of intermittence.

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