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INVIGORATION OF CRYSTAL SWEET CORN SEEDS BY HYDROPRIMING

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Abstract: Sweet corn is a vegetable that belongs to the special corn category. It is used exclusively in human food and differs from common green corn because it contains higher sugar content and lower starch content in its grains. The low availability of cultivars with desirable agronomic characteristics has been an obstacle to the expansion of the crop production in the country. Sweet corn seeds have germination problems and low vigor, which makes it difficult to establish the culture in the field. Hydropriming is a technique of physiological conditioning of seeds that consists of soaking seeds in water for certain periods of time, being a low-cost treatment that has shown to be very promising in the invigoration of low vigor seeds. The present work aimed to evaluate the effects of hydropriming in different aeration treatments and soaking periods on the physiological quality of crystal sweet corn seeds. The parameters of germination, seedling and radicle length, seedling dry matter and electrical conductivity were evaluated in view of the effects of aeration treatments by atmospheric air, concentrated oxygen, without aeration at different imbibition periods of 30, 60, 90 and 120 minutes, as well as the interactions between these treatments. According to the results obtained, the hydropriming treatment interacting with the atmospheric air aeration treatment provided an invigoration of the physiological quality of crystal sweet corn seeds.
Keywords: Horticulture; deterioration; hydration; oxygen; booth; uniformity.

INTRODUCTION

Sweet corn (Zea mays L., saccharata group, Gramineae) is intended for human consumption and can be consumed in two ways, either "in natura" or in preserves. This food is present in the Brazilian palate in several ways, being the main ingredient of many recipes. The production of sweet corn is almost exclusive to small and medium producers and has become a very profitable activity due to its demand and good market price, in addition to being a great alternative to be implemented in family farming. National production is concentrated in the states of Minas Gerais, São Paulo and Goiás (PEREIRA FILHO, 2002). Although there are no precise data on the average production and cultivated area in Brazil, in global parameters the cultivated area is 900 thousand hectares,

The sweet corn plant has the following agronomic characteristics: average height of 1.30 to 2.50 m, cylindrical, erect, fibrous stem, separated by buds, which are covered by a part of the leaf called the sheath. Its leaves vary in size, from dark green to light green, having flexibility, with a white central vein and smooth texture. The plant produces its tassel in its highest part, where the pollen grain and the ear are produced, which is found in the middle part of the plant. The ear produces threads in which, after fertilized, each one represents a grain of corn (PEREIRA FILHO, 2002).

Sweet corn seeds have a smaller pericarp thickness, a high endosperm sugar content, and a lower starch content compared to common corn seeds. The aforementioned characteristics make these seeds more susceptible to the attack of pathogens and their proliferation, which consequently causes the deterioration of the seed. This reduces the life and storage time of the seeds, also affecting the development in the field (AZANZA et al., 1996).

Seed quality can be subdivided into four aspects, namely: the physiological quality, which is defined by the germination potential and vigor, the genetic quality, which is determined by the genetic purity of cultivars or hybrids, the sanitary quality, which is defined by the absence of diseasecausing pathogens and weeds, and finally, the physical quality which is determined by the absence of contaminating material and other impurities. All the aforementioned aspects are equivalent in their importance in seed quality, guaranteeing seed vigor and, consequently, plant vigor (NETO, 2015).

The physiological quality of seeds is determined by the performance process of their vital factors, such as their germination capacity, vigor and longevity of this seed until at least its sowing. Therefore, the importance of maintaining this quality is highlighted, which is very important for the production process as it affects performance in the field (SILVA et al., 2008).Germination consists of the process in which the emergence and development of the seedling occurs, where a new plant originates. The vigor of a seed is the potential for a rapid and uniform emergence, developing normal plants under field conditions (BARROS NETO et al., 2014).

Physiological conditioning of seeds is a technique that can be used in small batches of stored seeds that are in the process of deterioration. Therefore, the use of the physiological conditioning technique aims to improve the physiological quality of seeds. Therefore, the technique has been considered as a seed refresher. (SILVA et al., 2014). Physiological conditioning consists of the controlled imbibition of seeds in different solutions, activating the metabolic processes of germination that are phases I and II, without the emission of the radicle, which corresponds to phase III (HEYDECKER et al., 1973).

Hydropriming is a low-cost seed conditioning technique that consists of controlled seed hydration, that is, soaking the seeds in water for certain controlled periods in order to promote an increase in germination and vigor (BISOGNIN et al, 2016). The technique provides benefits in relation to the vigor of the seeds, favoring the reduction of the average time of germination and emergence of seedlings, this reduces the period of exposure of the seeds to unfavorable environmental conditions for their development (MARCOS FILHO and KIKUTI, 2008).

The present work aimed to evaluate the effect of hydropriming on the invigoration of the physiological quality of crystal sweet corn seeds.

MATERIALS AND METHODS

The experiment was conducted in the seed laboratory of the University of Brasília (UnB) during the period from January to June 2021.

The seed used for the experiment was the variety of sweet corn crystal BR 402 harvests 2006/2007, supplied by Embrapa Vegetables, without any type of chemical treatment.

Crystal sweet corn seeds were submitted to three hydropriming methods, which were: immersion in non-aerated water, immersion in aerated water with atmospheric air and immersion in aerated water with concentrated oxygen around 100%. The soaking periods in which the crystal sweet corn seeds were exposed are: 30, 60, 90 and 120 minutes, plus the control that represented the time 0 minutes, as it was not soaked in water.

In order to carry out the hydropriming of the seeds, 180 grams of crystal sweet corn seeds were used per treatment, and these seeds were immersed in 400 ml of water, to carry out the treatment by hydropriming. Crystal sweet corn seeds with an initial moisture content of 13% bu (wet basis) were placed in glass containers, which have the following dimensions (diameter=9.05 cm; height=16.82 cm; neck=74 mm and useful volume = 830 ml). To allow aeration of the container with water, the lids were fitted with a hose for the inlet and outlet of the gas, which were connected to an air compressor and a Philips Respironics EverFlo stationary oxygen concentrate for the injection of air into the solution. conditioning.

After hydropriming, sweet corn seeds were placed to dry until reaching a constant mass for one week at ambient conditions, approximately 27^{0} C and 60% relative humidity.

The experiment was carried out in a 3x4 factorial scheme, with three hydroconditioning methods (immersion in non-aerated solution, immersion in aerated solution with atmospheric air and immersion in aerated solution with concentrated oxygen around 100%), and four periods of imbibition in water (30, 60, 90 and 120 minutes), in four replications, totaling 12 treatments plus the control. In the analysis of variance and breakdown of the means, the statistical software Sisvar 5.6 was used.

PHYSIOLOGICAL QUALITY TESTS GERMINATION PATTERN (TPG):

The seeds were placed on the germitest paperand covered with three more sheets of paper, moistened to 2.5 times their weight. Then they went to the germination chamber where they were monitored for 7 days. After this period, the percentage of seed germination was counted (BRASIL, 2009).

SEEDLING LENGTH (CP) AND ROOTLET LENGTH (CR):

The seedlings of the standard germination test (TPG) were used to evaluate the length of the shoot and root of the plant. With the aid of a ruler graduated in centimeters, the measurement of the area and radicle was performed and then the conventional calculation adapted by the method described by Nakagawa (1999) was performed.

SEEDLING DRY MATTER (MS):

Normal seedlings, obtained from germination tests, were evaluated, excluding the remaining endosperm. The repetitions of each treatment were placed in paper bags, identified, and taken to an oven with forced air circulation, maintained at a temperature of 80ºC for a period of 24 hours (NAKAGAWA, 1994). After this period, each repetition had its mass evaluated on a scale with a precision of 0.001g, and the average results were expressed in milligrams.

ELECTRICAL CONDUCTIVITY (CE):

It was obtained through 2 replications of 50 seeds of known mass, where they were soaked with 75 ml of distilled water in plastic containers for a period of 24 hours. After this period, the samples were submitted to a stirring process to homogenize the exudates that are released into the water and then the reading was performed with a previously calibrated conductivity meter (VIEIRA, 1994).

RESULTS AND DISCUSSION

In the analysis of variance (Table 1) it is observed that all parameters, treatments and soaking times were statistically significant at the 5% level by the Tukey test, with a splitting of the means. And in the variable of interaction between treatments and times (TREATMENT*TIME), the electrical conductivity parameter (EC) was the only one that proved to be non-significant at 5% probability by the Tukey test.

The coefficient of variation (CV) of all variables analyzed presented values below 40% (Table 1). This coefficient is used to estimate the precision of the experiment, where the experiments that have the lowest values of coefficient of variation are considered accurate. Agricultural experiments mostly use the coefficient of variation values proposed by Pimentel-Gomes (2009) in which CV values below 10% are considered low, between 10 and 20% as medium, 20 and 30% as high and above 30% very high. These proposed values are based on agricultural and field data.

Therefore, Garcia (1989) suggests the need to propose new CV values, in order to estimate values close to reality for each variable to be studied.

Analyzing values of coefficients of variation, it was observed in other seed studies, CV values close to the values present in this one (Table 1). Araújo et al. (2011) using the seed hydropriming treatment obtained CV values in the parameters of germination and dry matter close to the values described in the analysis of variance (Table 1), in which they are described as TPG for germination and DM for dry matter. Vanzolini et al. (2007) in their study evaluating the physiological quality of soybean seeds, demonstrate values of coefficients of variation in the parameters of seedling length (CP) and radicle length (CR) very close to those expressed in this work.

Table 2 shows that the variables seedling length (CP), radicle length (CR) and dry matter (DM) presented the best performances in the hydroconditioning treatment with atmospheric air aeration.Similar results were observed by Hölbig et al.(2011), demonstrating that the hydropriming treatment of onion seeds provided greater seedling development and greater accumulation of dry matter. As Balbinot and Lopes (2006) concluded that the conditioning of carrot seeds in distilled water with aeration system contributed to the increase of seed vigor.

In the standard germination test (TPG) variable, it is observed that the hydroconditioning treatments with atmospheric air aeration (AR ATM), concentrated O2 (O2 CONCEN.) and control obtained the highest germination rate compared to the treatment without aeration (table 2). These results are similar to those of Heydecker et al. (1975) in which he demonstrates that aeration proved to be essential in the synchronization of vegetable seed germination using the technique of physiological conditioning with osmotic solution.

In the electrical conductivity (EC) variable, it is observed that the hydroconditioning treatments with aeration (concentrated O2 and atmospheric air) and without aeration had less loss of solutes when compared to the control. These results demonstrate that the hydropriming treatment associated with aeration treatments favored the organization of seed membranes, thus reducing the loss of solutes, and the treatment with concentrated oxygen (concentrated O2) presents the lowest loss of solutes (Table 2) . It is important to emphasize that the lower the value of the electrical conductivity result, the greater the integrity of the cell membranes of the seed, which prevents the release of exudates in the imbibition solution. However, it can be said that the lower values of electrical conductivity indicate less deterioration of the seeds.

In the variable seedling length (CP), it is observed that the soaking time of 30 minutes had the best performance in relation to seedling growth (Table 3). Although there are no studies correlating the specific time of 30 minutes of seed imbibition to the hydropriming treatment with the increase in seedling length, studies such as those by Araújo et al. (2011) with gherkin seeds and Conde et al. (2021) with lettuce seeds, demonstrate that the treatment with seed hydropriming favors the growth of seedlings. Regarding germination, which corresponds to the TPG variable, the time that obtained the highest germination rate was the control when compared to the different imbibition times (Table 3). This result corroborates the idea of Marcos Filho (2005), where he says that,

The electrical conductivity (EC) variable showed less solute loss when the seeds were previously submitted to the hydropriming treatment and different soaking times when

	QM				
	CP	**CR**	**TPG**	**MS**	**CE**
TREATMENT	200. 815666*	56.543694*	943.307692*	0.618258*	529.451076*
TIME	21.226058*	4.422636*	169.064103*	0.032462*	530.680557*
TREATMENT*TIME	21.281402*	4.770696*	271.748718*	0.119943*	532.675432 ns
MISTAKE	4.627462	1.333535	59.897436	0.010566	113.358157
CV (%) =	31.03	35.46	18.19	24.86	13.50
Overall Average:	6.9330769	3.2564103	42.5384615	42.5384615	78.88559231

**Significant at 1% probability by F test. *Significant at 5% probability by F test. ns - Not significant by F test. TPG: standard germination test; CP: seedling length; CR: root length; MS: dry matter and EC: electrical conductivity.

Table 1. Analysis of variance of physiological quality characteristics in crystal sweet corn seeds submitted to hydropriming technique.

TREATMENTS	**CP**	**CR**	**TPG**	**MS**	**CE**
WITNESS	7.008333 b	3.015000 a	48.000000 b	0.450450 b	105.652500 b
O2 CONCEN.	4.747500 ab	2.228750 a	48.000000 b	0.253444 a	78.384125 a
ATM AR	11.923333 c	5.914583 b	46.750000 b	0.687038 c	75.684125 a
BREATHLESS	4.109583 to	1.686250 to	31.500000 to	0.290450 to	75.897875 to

Means followed by the same lowercase letter in the columns belong to the same group, according to Tukey's clustering criterion at 5% probability. TPG: germination pattern test; CP: seedling length; CR: root length; MS: dry matter and EC: electrical conductivity.

Table 2. Mean values obtained in the physiological quality characters of crystal sweet corn seeds submitted to the hydropriming technique with different aeration treatments.

TREATMENTS	**CP**	**CR**	**TPG**	**MS**	**CE**
0	7.008333 ab	3.015000 a	48.000000 b	0.450450 a1	105.652500 b
30	8.885556 b	4.068333 a	46.500000 ab	0.491450 a1	84.802333 ab
60	7.343889 ab	3.591111 a	42.333333 ab	0.389475 a1	73.352167 a
90	5.392222 a	2.483333 a	42.500000 ab	0.407442 a1	75.973333 a
120	6.085556 ab	2.963333 a	37.000000 a	0.352875 a1	72.493667 a

Means followed by the same lowercase letter in the columns belong to the same group, according to Tukey's clustering criterion at 5% probability. TPG: germination pattern test; CP: seedling length; CR: root length; MS: dry matter and EC: electrical conductivity.

Table 3. Mean values obtained in the physiological quality characters of crystal sweet corn seeds submitted to the hydropriming technique in different periods of imbibition.

compared to the control (Table 3). Evaluating the averages of the time treatments, it is observed that the times of 30, 60, 90 and 120 minutes presented lower averages when compared to the control treatment. This result demonstrates that the hydropriming treatment of the seeds at different times had beneficial effects on the invigoration of the seeds in relation to their deterioration. A study conducted by Giurizatto et al. (2008) in soybean seeds using the hydropriming treatment also showed similar results, where it was observed that the control seeds have higher values of electrical conductivity when compared with seeds submitted to hydropriming treatment.

The variables radicle length (CR) and dry matter (DM) did not show a significant difference in the different imbibition times (Table 3), however, if the averages of the time treatments are observed, it is noted that there was a tendency for the values to decrease according to soaking time is increased. Similar results were observed in the work of Maximiano (2017), in which corn seeds pre-conditioned in water did not obtain the best results in relation to the variables CR and MS when exposed to a time of 120 minutes of imbibition.

In table 4, observing the variables CP and CR, it is noted that the aeration treatment with atmospheric air provided better performance in seedling and radicle growth of sweet corn. And regarding the soaking periods of the variables CP and CR, it is observed that time 30 presented the best performance in relation to seedling and radicle growth. According to Nascimento (2004), working with physiological conditioning of vegetable seeds, with aeration from an aquarium pump that uses atmospheric air, observed that the use of aeration associated with the physiological conditioning treatment of the seeds promoted a reduction in the duration of the treatment, or be, it is possible to obtain satisfactory results in shorter periods of time of exposure of the seeds in solution when the conditioning treatment is associated with aeration. Therefore, the author considers aeration as a factor that directly affects the success of seed conditioning.

In the interaction table between treatments (Table 4) when observing the germination variable (TPG), it is noted that the treatments of aeration by atmospheric air and concentrated O2 at imbibition times of 60, 90 and 120 obtained the highest germination rate. of seeds. According to Souza et al. (2012), an increase in the germination rate of chive seeds is observed when exposed to the hydropriming treatment for longer periods of imbibition. When the time periods of seed imbibition were evaluated, focusing on the percentage of germination (TPG), it was noted that in general there was no significant interaction between the different periods of exposure to the hydropriming treatment. This information corroborates the result obtained by Saha et al. (1990) working with soybean seeds exposed to the controlled hydration treatment,

In the dry matter (DM) variable, it was observed that the hydroconditioning treatment using atmospheric air aeration provided greater accumulation of dry matter. And with regard to soaking periods, times 60, 90 and 120 provided greater accumulation of dry matter (Table 4). Similar results were observed by Bisognin et al. (2016) in their work with hydroconditioned cabbage seeds, where they showed greater accumulation of seedling dry matter when the period t and imbibition time was increased.

In the electrical conductivity (EC) variable, although the interaction analysis (Table 4) did not show significant differences between any of the treatments for both aeration and soaking periods, a decrease in the mean values

SOILING PERIODS
AERATION CHARACTERISTICS 30 60 90 120
O2 CONCENT9.70 bB 3.96 aA 2.61 aA 2.70 aA
CP AR ATM11.03 bA 4.00 bA 0.07 bA 12.58 bA
BREATHLESS5.91 aA 4.07 aA 3.48 aA 2.96 aA
O2 CONCENT4.49 bB 1.85 aA 1.27 aA 1.29 aA
CRATM AR5.47 bA 6.89 bA 4.86 bA 6.42 bA
BREATHLESS2.23 aA 2.02 aA 1.31 aA 1.17 aA
O2 CONCENT51.00 aA 53.00 bA 46.00 bA 42.00 bA
TPG AR ATM41.00 aA 46.50 bA 52.50 bA 47.00 bA
BREATHLESS47.50 aB 27.50 aA 29.00 aA 22.00 aA
O2 CONCENT0.56 bB 0.19 aA 0.11 aA 0.12 aA
MSATM AR0.54 bA 0.70 bAB 0.81 bB 0.69 bAB
BREATHLESS0.36 aA 0.26 aA 0.29 aA 0.23 aA
O2 CONCENT82.89 aA 80.23 aA 78.78 aA 71.61 aA
CE AR ATM89.75 aA 67.21 aA 75.32 aA 70.43 aA
BREATHLESS81.75 aA 72.60 aA 73.80 aA 75.43 aA

Means followed by the same lowercase letter in the columns do not differ statistically by Tukey's test at 5% probability, for each characteristic separately. Means followed by the same capital letter in the lines do not differ statistically by Tukey's test at 5% probability, for each characteristic separately. TPG: germination pattern test; CP: seedling length; CR: root length; MS: dry matter and EC: electrical conductivity.

Table 4. Interaction between aeration factors and soaking period on the physiological quality of crystal sweet corn seeds submitted to the hydropriming technique.

of the amount of solutes released by the seed as the period of exposure to hydropriming increases. Similar results were observed by Caseiro (2003) in a study carried out with onion seeds submitted to the physiological conditioning treatment, where the control showed higher conductivity results, when compared to the treatments that received physiological conditioning, that is, there was an organization of the membranes of the seeds exposed to the treatment, reducing the loss of solutes.

CONCLUSION

The hydropriming treatment with atmospheric air provided an invigoration of the physiological quality of crystal sweet corn seeds.

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