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EFFECT OF PACKAGING MATERIALS AND STORAGE ENVIRONMENT ON FENNEL SEEDLING GROWTH

EFEITO DA EMBALAGEM E DO AMBIENTE DE ARMAZENAMENTO NO CRESCIMENTO DE PLÂNTULAS DE ERVA DOCE

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ABSTRACT: The objective of the present study was to assess the influence of the packaging material (cotton cloth bag, multifolium paper and glass container) and storage environment (laboratory and cold chamber conditions) on fennel seedling growth. Seeds were placed in different packaging materials and exposed to the two environments for twelve months. Assessments were made before storage and at every two months and the following were determined: total emergence, emergence speed index, seedling fresh and dry matter. A completely randomized experimental design was used, with four replications in a 2 x 3 x 6+1 factorial design in split split plots, where the plot was the storage environment (laboratory and cold chamber conditions); the split plot was the storage (cotton cloth bag, multifolium paper and glass container) and the split plot was the storage periods (2, 4, 6, 8, 10 and 12 months) and plus an additional treatment (before storage). The results showed that the fennel seedlings had superior growth when their seeds were placed in the glass packaging material, regardless of the storage environment.

KEYWORDS: *Foeniculum vulgare*. Seeds. Deterioration. Storage.

INTRODUCTION

Fennel (*Foeniculum vulgare* Miller), also known as Florence fennel, is a plant belonging to the family Apiaceae and widely cultivated throughout Brazil, where it is cultivated in the south central and northeastern states, occurring spontaneously in the southern states from dispersed seeds after cultivation. (LORENZI; MATOS, 2002). This species has medicinal, seasoning and aromatic properties; the seeds, roots and leaves are used for therapeutic purposes. The components of this plant act on the digestive and respiratory systems (TESKE; TRENTINI, 1995). The essential oil is

flavoring in breads, cakes and cookies (MARTINS, 1999), while the bulb is much used in cold salads.

The use of vigorous with high germinating power is considered the main requisite to obtain more strongs seedlings, which result in higher yields in the commercial exploitation of the crop. According to Nascimento et al. (2006), between the harvest and sowing seasons, storage is an important stage in a seed production program. The main concern during the storage period is seed quality preservation, by endeavoring minimize the speed of the deterioration process, since one of the symptoms of this process is fall in quality during storage.

To better preserve the seeds, knowledge is essential on the conditions under which they will be stored. According to Carvalho and Nakagawa (2012), in addition to conditions of temperature and relative humidity in the storage environment, the type of packaging material used for seed storage also influences their longevity, affecting the speed of the biochemical processes related to deterioration. When seeds are kept under controlled temperature and relative humidity conditions, these factors determine viability maintenance, the also reducing the loss gor.

Fennel is propagated by seeds; therefore it is necessary to know the appropriate methods for preserving its seeds, because they have high commercial value, allied to the fact that many of the producers use seeds from their own fields, obtained, very often, without rigorous selection criteria.

Thus the objective of the present study was to assess the fennel seedling growth after placing their seeds in different packaging materials and storage in different environments.

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MATERIAL AND METHODS

The experiment was carried out in the Sector of Weeds and Medicinal Plants and in a greenhouse, both belonging to the Agricultural Science and Technology Center (Centro de Ciências e Tecnologias Agropecuárias - CCTA) of the Darcy Ribeiro North Fluminense State University (UENF), in Campos dos Goytacazes – RJ, Brazil.

The fennel seeds used in this experiment were acquired from a commercial plantation located in the municipality of Simão Dias - SE, Brazil. The seeds were placed in three types of packaging materials: cotton cloth bags, multifolium paper and hermetically sealed glass containers, all with a capacity of 200 grams.

The different types of packaging materials containing the seeds were stored in the environmental conditions of the laboratory and in a cold chamber (15.7°C and 60% UR) for a twelve-month period.

The temperature and relative air humidity data recorded in the laboratory environment throughout the experimental period, when the temperature ranged from 21.6 to 28.6ºC and the relative humidity, from 69 to 80% (Figure 1).

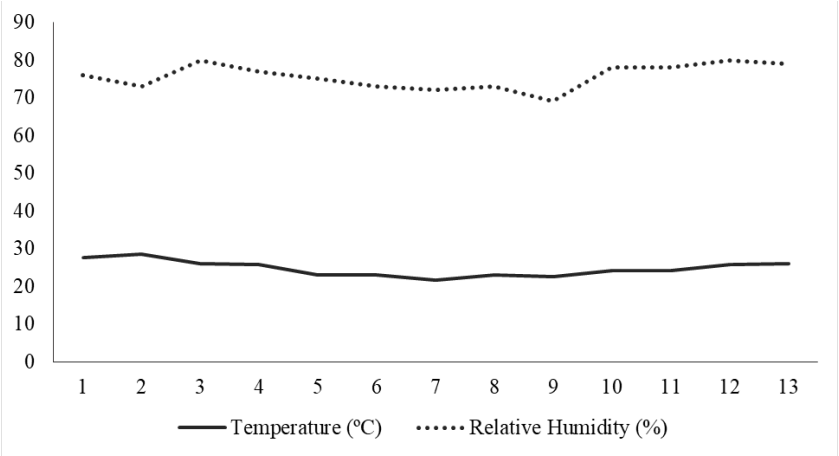

Figure 1. Monthly mean temperature and relative humidity, recorded in the laboratory environment during the fennel seed storage.

The seed physiological quality was assessed, in greenhouse, before storage and until twelve months at two monthly intervals. The seeds were sown on 128-well extruded polystyrene trays, filled with commercial Basaplan substrate, placing one seed 2 cm deep in each well. They were irrigated daily.

The characteristics assessed in this study were:

Total emergence (ET): the percentage of total seedling emergence was determined by counting the number of emerged seedlings at the last ESI assessment.

Emergence speed index (ESI): the emerged seedlings were counted daily starting from the emergence of the first seedling until the 14th day. The ESI was calculated following the formula proposed by Maguire (1962).

Seedling fresh (MF) and dry matter (MS): At the end of the total emergence test, the seedlings were removed from the trays taking care not to damage the root system, washed in the greenhouse, dried on absorbent paper in trays and taken to the laboratory, where they were weighed on precision scales to determine the fresh matter. The seedlings were then placed in paper bags and dried in a forced air circulation chamber at 70°C for 72 hours. The dry matter was determined by weighing on precision scales and the results were expressed in milligram per seedling (mg seedling^{-1}).

Statistical analysis

A completely randomized experimental design was used, with four replications in a 2 x 3 x 6+1 in split split plots. The plot was the storage environment (laboratory and cold chamber conditions); the split plot was the packing material (cotton cloth bag, multifolium paper and glass container) and the split split plot was the storage periods (2, 4, 6, 8, 10 and 12 months) and plus an additional treatment (before storage). The experimental data were submitted to analysis of variance. The physiological quality of the seeds stored in the three types of packaging materials in each storage environmental condition and each storage period was compared by the Tukey test at 5% probability. Regression analysis was applied to the storage period in all the characteristics assessed.

RESULTS

The results of the emergence speed index, total emergence, fresh matter and dry matter of the fennel seedlings before seed storage, showed that the fennel seeds were vigorous, with 86.0% emergence (Table 1).

Table 1. Mean values of the emergence speed index (ESI), total emergence (TE), fresh matter (FM) and dry matter (DM) of the seedlings derived from fennel seeds before storage.

ESI	TE	FM	DM
	---%---	---mg---	---mg---
21,62	86,00	1851,7	155,6

The fennel seedlings initially presented good quality, with over 80% emergence, for both storage conditions. As the seed storage period increased, there was linear reduction in the seedling emergence percentage, both in the laboratory and cold chamber environmental conditions (Figures 2 and 3).

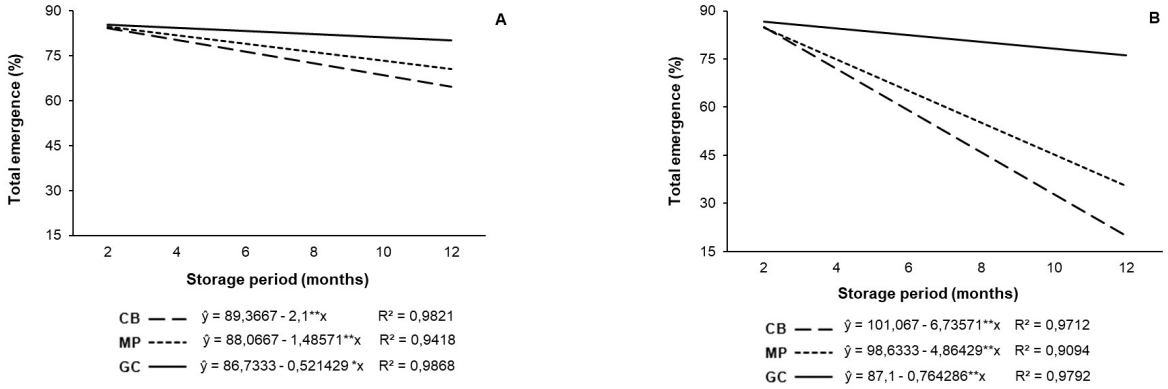

Figure 2. Total emergence of fennel seedlings from seeds stored in cotton cloth bag (CB), multifolium paper (MP) and glass container (GC) and stored under cold chamber (2.A) and laboratory (2.B) environmental conditions in function of the storage period.

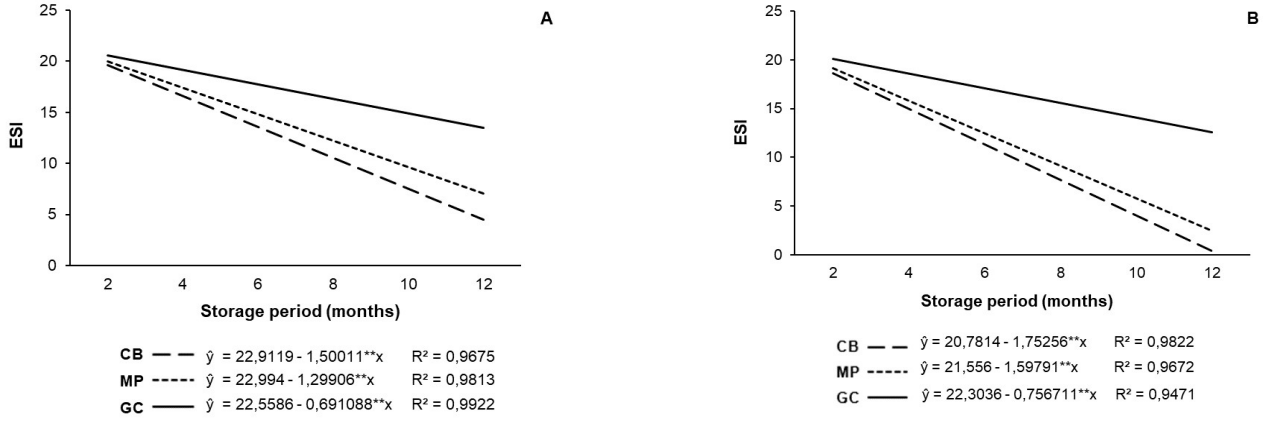

Figure 3. Emergence speed index of fennel seedlings from seeds stored in cotton cloth bags (CB), multifolium paper (MP) and glass container (GC) and stored under cold chamber (3.A) and laboratory (3.B) environmental conditions in function of the storage period

Under laboratory conditions, reduction in seedling emergence was more marked than that observed in the cold chamber, especially when the seeds were packaged in cotton cloth bags and multifolium paper, with approximately, 17.0 and 34.0% emergence, respectively, at twelve months storage. However, in the cold chamber conditions, the emergence of seedlings from seeds stored in the chilled packaging was approximately 64.0 and 70.0%, respectively. It was further observed that seedlings from seed stored in glass packaging presented bigger emergence, with values of approximately 75.0% under laboratory conditions and 80.0% under cold chamber conditions (Table 2).

Table 2. Mean total emergence values (%) of fennel seedlings, from seeds stored in cotton cloth bags (CB), multifolium paper (MP) and glass containers (GC), according to the environment and storage period

Packaging type	Storage period (months)					
	2	4	6	8	10	12
			Laboratory			
CB	83,00 A	75,00 B	65,00 C	51,00 C	32,50 C	17,00 C
MP	83,00 A	79,50 AB	74,00 B	67,00 B	50,00 B	34,00 B
GC	85,00 A	84,50 A	83,00 A	81,00 A	79,00 A	75,00 A
			Cold chamber			
CB	84,00 A	82,50 A	76,00 B	72,00 B	69,00 B	64,00 B
MP	84,50 A	83,00 A	80,00 AB	76,00 B	73,00 B	70,00 B
GC	85,00 A	85,00 A	84,00 A	83,00 A	81,50 A	80,00 A

For each environment, means followed by the same letter in the column do not differ at 5% level of probability by the Tukey test.

Table 2 shows the fennel seedling emergence percentage from seeds stored in different packaging materials and environments, for twelve months. Considering the laboratory condition, it was observed that there was no difference in seedling emergence between the packaging materials at two months storage. At four months, the emergence of seedlings from the seeds stored in the glass container packaging was statistically equal to those stored in multifolium paper, but different from the glass container packaging for laboratory storage. From the sixth month onwards, seedling emergence was different among the packaging materials, and the glass container packaging resulted in a higher percentage, followed by the multifolium paper and lastly by the cotton cloth bags, that presented the worst performance, reaching approximately 17.0% emergence in contrast to the glass container packaging that obtained approximately 75.0% at 12 months storage.

In the cold chamber, the seedling emergence percentage was similar for the types of packaging materials at two and four months storage. In the other assessment periods, emergence was higher when the seeds were stored in glass containers, and at six months, the multifolium paper packaging also gave a result similar to the glass container (Tabela 2).

The seedling emergence speed decreased, giving linear and decreasing responses during the storage period, both in the laboratory and cold chamber conditions (Figures 3.A and 3.B).

In laboratory conditions, the emergence speed index of fennel seedlings were statistically equal in all the packaging materials used only at two months of storage. In the other storage periods, the cotton cloth bag and multifolium paper packaging materials resulted in similar emergence speed indexes that were inferior to those obtained when the seeds were stored in glass containers (Table 3).

In the cold chamber, the seedling emergence speed index was similar in the two and four month storage periods, regardless of the packaging materials used to store the seeds. At six months, the glass container packaging presented emergence speed index similar to that of the multifolium paper packaging material, but superior to the cotton cloth bag packaging material. At eight, ten and twelve months storage, fennel seedlings presented highest emergence speed index when the seeds were stored in glass containers.

Table 3. Mean values of the emergence speed index of fennel seedlings, derived from seeds stored in cotton cloth bags (CB), multifolium paper (MP) and glass containers (GC) according to the storage environment and period

Packaging type	Storage period (months)					
	2	4	6	8	10	12
			Laboratory			
CB	19,46 A	12,81 B	8,66 B	5,71 B	3,07 B	1,37 B
MP	19,62 A	15,10 B	10,03 B	8,42 B	6,02 B	3,02 B
GC	20,40 A	19,68 A	17,59 A	16,49 A	15,10 A	12,77 A
			Cold chamber			
CB	19,82 A	16,70 A	14,23 B	10,67 B	8,73 B	4,31 B
MP	19,87 A	17,80 A	15,27 AB	13,75 B	10,11 B	6,60 B
GC	20,78 A	19,95 A	18,38 A	17,83 A	15,68 A	13,74 A

For each environment, means followed by the same letter in the column do not differ at the level of 5% probability by the Tukey test.

The regressions (Figures 4A. and 4.B) showed that under laboratory conditions, the seedling fresh matter decreased linearly during seed storage, and the seedlings that were obtained from seeds stored in the cotton cloth bag and multifolium paper packaging materials showed more accentuated decrease, reaching low values, that were 33.2 and 60.2 mg, respectively, compared to those obtained from the seeds stored in the glass container packaging, whose value was 648,6 mg (Table 4).

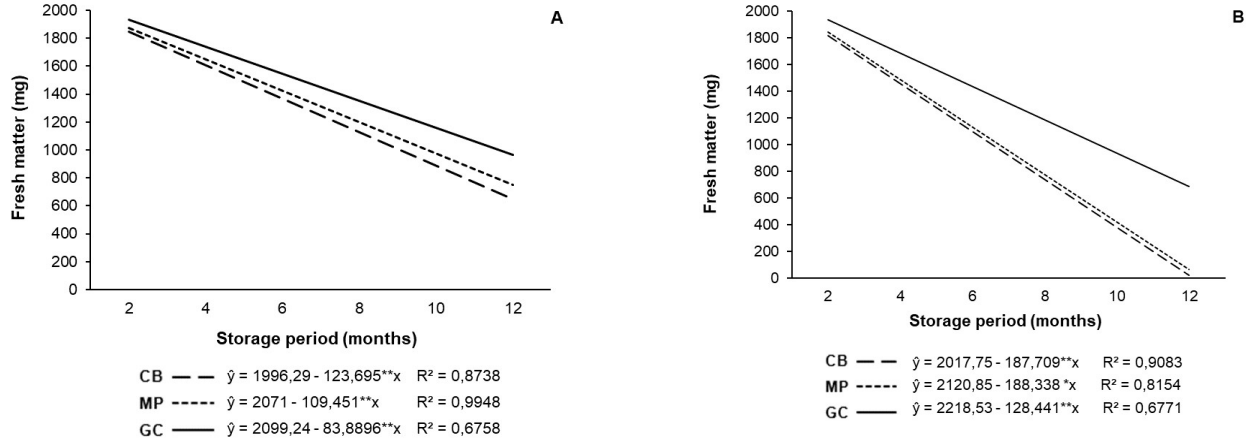

Figure 4. Fresh matter of fennel seedlings from seeds stored in cotton cloth bags (CB), multifolium paper (MP) and glass container (GC) and stored under cold chamber (4.A) and laboratory (4.B) environmental conditions in function of the storage period.

Table 4. Fresh matter mean values (mg) of fennel seedlings from seeds stored in cotton cloth bags (CB), multifolium paper (MP) and glass containers (GC) according to storage environment and period.

Packaging type	Storage period (months)					
	2	4	6	8	10	12
			Laboratory			
CB	1841,8 A	1266,4 B	778,8 B	212,9 B	89,4 B	33,2 B
MP	1842,6 A	1447,7AB	821,7 B	517,4 B	125,1 B	60,2 B
GC	1848,2 A	1715,1 A	1596,8 A	1287,1 A	820,6 A	648,6 A

			Cold chamber			
CB	1845,3 A	1589,3 A	1104,2 B	821,7 B	740,4 B	680,4 A
MP	1846,8 A	1677,3 A	1367,5AB	1185,7AB	991,0 AB	761,6 A
GC	1849,2 A	1780,0 A	1637,6 A	1494,2 A	1348,8 A	962,1 A

For each environment, means followed by the same letter in the column do not differ at the level of 5% probability by the Tukey test.

In the cold chamber, the fennel seedlings also presented reduction in fresh matter with increase in storage time of their seeds, regardless of the packaging material used. It was verified that reduction in the seedling fresh matter was less when the seeds were stored in a cold chamber than when stored under laboratory conditions.

Considering storage under laboratory conditions, the results showed that the fresh matter of the fennel seedlings did not differ statistically due to the packaging material used to store their seeds at two months storage (Table 4). At four months storage, the glass packaging material presented results similar to the multifolium paper, but different statistically from the cotton cloth bags. From the sixth storage month onwards, the seed stored in the glass packaging material had the biggest seedling dry matter weight compared to the other to packaging materials.

Analysis of the seed stored in a cold chamber showed that at two, four and twelve months storage, there was no difference in the seedling fresh matter between the packaging materials used to store the seeds. At six, eight and ten months storage, the fresh matter of the seedlings derived from seeds packaged in cotton cloth bags was similar to those obtained from seeds packaged in multifolium paper. However, it was lower than that of seedlings whose seeds were storage in glass packaging, which presented the heaviest fresh matter weight.

The results for the fennel seedling dry matter after storing their seeds for twelve months (Figures 5.A and 5.B). It was observed that the seedling dry matter decreased linearly, regardless of the packaging material used to store the seeds and the storage environment. As the seedlings obtained from seeds stored in glass containers presented bigger dry matter weight, followed by the seedlings derived from seeds packaged in multifolium paper, and with less weight, to those whose seeds were packaged in cotton cloth bags. This was observed in both the storage conditions.

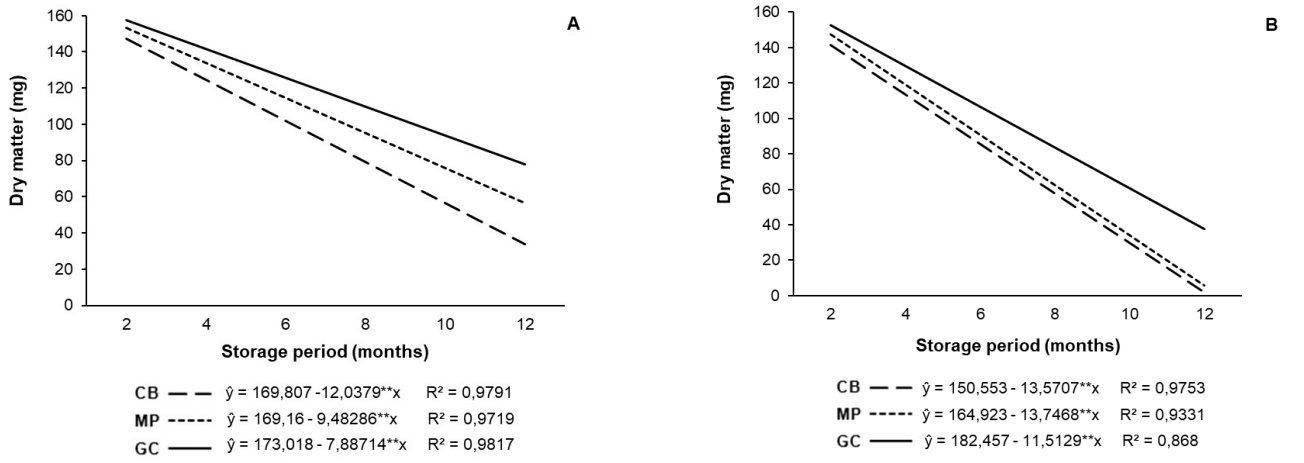

Figure 5. Dry matter of fennel seedlings from seeds stored in cotton cloth bags (CB), multifolium paper (MP) and glass container (GC) and stored under cold chamber (5.A) and laboratory (5.B) environmental conditions in function of the storage period

Considering storage under laboratory condition, the fennel seedling dry matter weight did not differ statistically among the packaging materials used to store the seeds at two months storage. For the other storage times, the seedling dry matter was bigger when the seeds were stored in

glass containers, and at four months storage, the multifolium paper packaging also presented a result similar to the glass container packaging (Table 5).

Table 5. Dry matter mean values (mg) of fennel seedlings from seeds stored in cotton cloth bags (CB), multifolium paper (MP) and glass containers (GC) according to the environment and storage period.

Packaging type	Storage period (months)					
	2	4	6	8	10	12
			Laboratory			
CB	148,1 A	81,1 B	65,8 B	15,6 B	14,4 B	8,2 B
MP	150,1 A	103,6 AB	85,2 B	29,2 B	20,2 B	11,7 B
GC	153,1 A	134,7 A	119,8 A	99,7 A	67,5 A	36,3 A
			Cold chamber			
CB	152,2 A	119,6 A	89,3 B	72,9 B	45,8 B	32,2 B
MP	153,3 A	129,0 A	109,2 AB	101,3 AB	65,2 AB	59,4 AB
GC	154,0 A	144,9 A	124,4 A	115,8 A	88,4 A	79,2 A

For each environment, means followed by the same letter in the column do not differ at the level of 5% probability by the Tukey test.

In the cold chamber storage, the three packaging materials used to store the seeds resulted in similar seedling dry matter at two and four months storage. From the sixth month onwards, the dry matter of the seedlings from seeds stored in the glass container packaging was similar to that in seedlings whose seeds were packaged in multifolium paper. However, they were superior to those obtained when cotton cloth bag packaging was used to store the fennel seed.

DISCUSSION

The reduction in seedling emergence was probably related to the high temperatures and relative humidity that occur under laboratory conditions, associated to the type of packaging materials used to store the seeds. These factors are enough to promote higher respiratory rates, causing increase in seed reserve consumption and accelerating the deterioration speed (Table 2).

Guedes et al. (2010), studied cumarú (Amburana cearensis) seed germination and also observed reduced emergence percentage during storage, after the seeds had been stored in Kraft paper, cotton cloth and aluminum paper bags and stored in laboratory and refrigerator environments.

Vieira and Gusmão (2008) verified that pitombeira (*Talisia esculenta*) seedling emergence decreased due to the storage period (60 days) under laboratory conditions, using paper bags for storage. After 30 days storage, there was no seedling emergence.

Torres et al. (2002) observed that cassava seeds presented good emergence when they were placed in plastic bags, paper bags and plastic boxes and stored in a cold chamber, and only the plastic box packaging also resulted in similar emergence when stored in laboratory conditions, at eight months storage.

It was observed that in the seedlings from the seeds stored in the packaging materials cotton cloth bags and multifolium paper, the emergence speed decreased more drastically compared to those stored in glass containers, regardless of the storage environment condition. These results were similar to data obtained in the emergence test, in which it was verified that the highest emergence percentages were observed when the glass container packaging was used, regardless of the storage environment condition because the multifolium paper is semipermeable and the cotton cloth bag is permeable (Marcos Filho, 2005). Therefore, the fennel seed physiological quality was best maintained in an impermeable packaging, because it attenuated the effects of deterioration.

Caldeira et al. (2016) also found that the emergence velocity index of tobacco seedlings decreased due to the storage period, when the seeds were packaged in aluminum packaging and stored in cold and dry chamber (10°C and 50% UR).

This shows the better maintenance of fennel seed physiological quality when they are stored at low temperature and low relative humidity.

These factors influence directly the seed water content so that it is important to use impermeable packaging material to prevent fluctuations in the degree of moisture in the seeds. This can reduce metabolic activity, because of the low moisture content, enabling maintenance of the physiological quality for a more prolonged period and low deterioration (CARDOSO et al., 2012).

According to Bragantini (2005), temperature and relative humidity are the most important factors in seed conservation. Increase in these factors can intensify seed respiratory activity, accelerating the deterioration process and, consequently, damaging seedling formation.

In watermelon, Torres (2005) also observed that in seeds stored in a cold chamber had better physiological quality than those stored in environmental conditions.

Bahry et al. (2008) observed that preservation of millet seed physiological quality, for 18 months, was better in a cold chamber than in the uncontrolled environmental condition, which is in agreement with the findings of the present study.

The treatment using the glass container packaging material generally showed better results of the variables analyzed in the present study, regardless of the storage condition. The glass container packaging material, probably because it is considered impermeable, preserved more the physiological quality of the fennel seeds, permitting better development of the fennel seedlings.

These findings corroborate Silva et al. (2010), who observed that the use of impermeable packaging material gave higher physiological quality indexes to rice, corn and beans seeds compared to permeable packaging materials. Meireles et al. (2011) also verified that papaya seeds, with low water content, presented better physiological quality when stored in impermeable packaging materials.

CONCLUSIONS

The fennel seedling physiological quality and growth were best when the seeds were stored in glass containers, regardless of the storage environment.

The cotton cloth bag packaging material was the least efficient in preserving the fennel seeds, both in the environmental and cold chamber conditions.

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RESUMO: O objetivo deste trabalho foi avaliar a influência da embalagem (saco de algodão, papel multifoliado e vidro) e do ambiente de armazenamento (condições de laboratório e câmara fria) no crescimento de plântulas de erva doce. Para isso, as sementes foram acondicionadas nas diferentes embalagens e expostas aos dois ambientes durante doze meses. As avaliações foram feitas antes do armazenamento e a cada dois meses, tendo sido determinado: emergência total, índice de velocidade de emergência, massa fresca e seca das plântulas. Utilizou-se o delineamento experimental inteiramente casualizado, com quatro repetições, num esquema fatorial 2 x 3 x 6 + 1 em parcelas subsubdivididas, no qual a parcela foi o ambiente de armazenamento (condições de laboratório e câmara fria); a subparcela as embalagens (saco de algodão, papel multifoliado e vidro) e a subsubparcela os períodos de armazenamento (2, 4, 6, 8, 10 e 12 meses) e mais um tratamento adicional (antes do armazenamento). Pelos resultados, demonstrou-se que as plântulas de erva doce apresentaram crescimento superior quando suas sementes foram acondicionadas na embalagem de vidro, independente do ambiente de armazenamento.

PALAVRAS-CHAVE: *Foeniculum vulgare*. Sementes. Deterioração. Armazenamento.

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