International Journal of Agriculture and Wildlife Science (IJAWS), 2020, 6(3): 416 - 422
doi: 10.24180/ijaws.743002

International Journal of Agriculture and Wildlife Science

http://dergipark.org.tr/ijaws

Research Article

Changes in Seed Germination during Storage of Flower Seeds: Species Differences

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Received: 28.05.2020 Accepted: 26.08.2020

Keywords:
Seed moisture, storage temperature, storage duration, flower seeds,

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Abstract. This work was carried out to test the storage longevity of seeds from 10 different flower species (Dahlia, Pelargonium, Salvia, Zinnia, Petunia, Gazania, Antirrhinum, Viola, Impatiens and Tagetes). Four lots of each species were stored at 25°C for 12 and 5°C for 24 months at 6±0.5% seed moisture in hermetic conditions. After both storage conditions, the seed lots of pelargonium, gazania, zinnia and tagetes had an average germination rate of 100%, while antirrhinum, petunia, impatiens, viola, salvia and dahlia seeds had lower germination rates varying by species. The decrease in germination of antirrhinum, petunia, impatiens, salvia, dahlia and viola seed lots after 24 months storage at 5°C was 55, 29, 21, 11, 8, and 8%, respectively. The decrease in germination of salvia, dahlia, impatiens, viola, antirrhinum, and petunia seeds after 25°C storage for 12 months was 38, 15, 9, 8, 5, and 4%, respectively. The results showed that extent of seed deterioration varied among the species and should be considered for seed storage practices of flower seeds. The reasons for differences in storage behaviour of the species were discussed.

Çiçek Tohumlarının Muhafazası Sırasında Tohum Çimlenmesindeki Değişimler: Tür Farklılıkları

Anahtar kelimeler:
Tohum nemi, depolama sicakliği, depolama süresi, çiçek tohumlari

Özet. Bu çalışma 10 farklı çiçek türü tohumunun (yıldız çiçeği, sardunya, adaçayı, kirli hanım, petunya, koyungözü, aslanağzı, menekşe, cam güzeli ve kadife çiçeği) depolama ömrünü test etmek ve türler arasındaki farkı saptamak için yapılmıştır. Her bir türden dört tohum partisi, hermetik koşullarda 25°C'de 12 ay ve 5°C'de 24 ay boyunca %6±0.5 tohum neminde depolanmıştır. Her iki depolama koşulundan sonra, sardunya, koyungözü, kirli hanım çiçeği ve kadife çiçeği tohum lotlarında ortalama %100 çimlenme gerçekleşirken, aslanazğı, petunya, camgüzeli, menekşe, adaçayı ve yıldız çiçeği tohumlarında türlere göre değişen daha düşük seviyede çimlenme oranları oluşmuştur. Aslanağzı, petunya, cam güzeli, adaçayı, yıldız çiçeği ve menekşe tohumu partilerinin çimlenmesindeki azalma, 5°C'de 24 ay depolandıktan sonra sırasıyla % 55, 29, 21, 11, 8, 8 olarak saptanmıştır. Adaçayı, yıldız çiçeği, cam güzeli, menekşe, aslanağzı ve petunya tohumlarının çimlenmesindeki düşüş, 12 ay boyunca 25°C'de depolandıktan sonra ise sırasıyla % 38, 15, 9, 8, 5, 4 olmuştur. Sonuçlar, tohum depolanabilirliğinin türler arasında değiştiğini ve çiçek tohumlarındaki tohum muhafaza koşullarında dikkate alınabileceğini göstermiştir. Türlerin depolama sürecindeki farklılıkların nedenleri tartışılmıştır.

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INTRODUCTION

The longevity of the seed depends primarily on the temperature, relative humidity and oxygen factors during storage (Doijode, 2001). As a general rule, the lower the seed moisture content and temperature, the longer the seed survival. Commercial seed storage is conducted at 12-15°C temperatures with 40-60% relative humidity for medium-term storage (12-36 months). Seed moisture content for small-seeded species is supposed to be 5-7% for an ideal storage environment. These seed moisture percentages are also used for both commercial and long-term storage in seed gene banks (Walters, 2015).

When carrying over seeds, those that are left over from an earlier production year need to be used for the next growing season so seed lots must be stored in optimum conditions. Nonoptimal storage environment is the basic reason for inducing seed ageing/vigour and in turn reducing seedling emergence potential. Ideal storage conditions are not always possible during seed production. In some cases, seed lots are stored at ambient storage conditions (seed merchant's uncontrolled warehouse) at the prevailing temperatures which can be high in some regions (25-35°C).

There are extensive studies about storage behavior of crop seeds (Walters, 2015), but few studies about flower seeds. However, conserving high seed germination is a prerequisite not only for obtaining a high percentage of seedling emergence in modules but also in breeding programs for future improvement of bedding plants. Carpenter *et al*. (1995a) suggested 15 or 25°C storage may be adequate for annual flowering plants that are stored commercially for 1 year, but for longer storage temperatures lower than 15°C are needed. Similarly, germination after storage at 5°C was found to be higher than that after storage at 15 or 25°C for Delphinium (Carpenter and Boucher, 1992) and Gerbera (Carpenter *et al*., 1995b) seeds. Large number of flower seeds exhibit dormancy. Relatively short periods of prechilling and use of low concentration of potassium nitrate solution (KNO_3) are common dormancy-breaking techniques used in germination tests (Baskin and Baskin 2001). Uniform germination and fast radicle emergence can be an important asset for high quality transplant production which may be influenced by storage conditions (Carpenter *et al*., 1995b). Therefore, optimum flower seed storage has an important issue for not only maintaining seed quality but also producing high quality transplant production.

The genetic structure of seeds plays a role in storability, so certain flower species store better than others. McDonald (2005) classified flower seeds into short (less than 1 year), medium (up to 2-3 year) and long (more than 3 years) storage categories and suggested that if a seed has a short storage life then it is prudent to purchase new seed on an annual basis. In all cases, understanding the species-based seed storage behaviour of flower seeds is important for seed companies since extensive inventories of seed are maintained and to ensure that the value of the seed is not lost during storage.

Our research objectives were to compare the germination percentages after storing the seeds of ten species with 6 ± 0.5% seed moisture content for 12 months at 25°C and for 24 months at 5°C.

MATERIAL AND METHOD

Four seed lots from each of ten flower species of Dahlia, Pelargonium, Salvia, Zinnia, Petunia, Gazania, Antirrhinum, Viola, Impatiens and Tagetes (Table 1) were obtained from commercial seed companies. Initial seed moisture content was determined using the low temperature (103 °C, 17 h, 0.5 g x 2 replicates) oven method (ISTA, 2016). Laboratory germination test conditions are presented in Table 1 and changed according to the species. Four replicates of 25 seeds were placed on filter paper (Filtrak, Germany) in a petri dish (9 cm) and subsequently placed in appropriate conditions for the germination test. The dishes were placed in polyethylene bags to prevent evaporation and placed in an incubator at 20°C. Total germination percentages (2 mm radicle emergence) were evaluated after the germination period specified for each species. All flower species seeds were germinated at 20°C but light, prechilling and KNO_3 were applied (+) or not (-) as shown in each species (Table 1). Light was applied as 750 lux for 12 h of a day throughout the germination test. Prechilling was applied at 5°C, on wet Whatman papers in petri dishes over 7 days in dark, then petri dishes were transferred to germination temperature (20°C). 0.2% KNO_3 was used as germination medium instead of distilled water during germination (Table 1).

Storage longevity was determined for 12 and 24 months at 25 °C and 5 °C, respectively. Seed moisture was adjusted to 6% ± 0.5% (fresh weight basis). Two subsamples of 100 seeds from each seed lot were stored at 5 and 25 °C in airtight laminated aluminium foil packets. Samples were taken from the storage packets after 12 months at 25 °C and 24 months at 5 °C. Germination tests were conducted in appropriate germination conditions as shown in Table 1- and 2-mm radicle protrusion was considered as germination.

Statistical analysis was conducted using the Statistical Package for Social Sciences (SPSS, Chicago, IL) by using analyses of variance. Separation between initial germination and germination after storage was made at the 5% level by the Duncan multiple range test.

Table 1. Germination test conditions of flower seeds.
Çizelge 1. Çiçek tohumlarının çimlenme testi koşulları.

	Germination conditions					
Species	**Temperature (°C)**	**Light ***	**Prechillling****	**KNO_3*****	**Period (day)**	**Seed m.c (%)**
Dahlia variabilis	20	–	+	–	21	6.0-6.5
Pelargonium spp.	20	–	+	–	28	5.8-6.2
Salvia splendens	20	–	+	–	21	6.0-6.4
Zinnia elegans	20	+	+	+	10	6.2-6.5
Petunia grandiflora	20	–	+	+	14	6.0-6.1
Gazania splendes	20	–	+	–	21	6.0-6.5
Antirrhinum chimes	20	–	+	+	21	6.0-6.3
Viola hybrida	20	–	+	+	21	5.9-6.3
Impatiens walleriana	20	+	+	+	21	6.0-6.3
Tagetes erecta	20	+	–	–	14	6.0-6.5

12h:12h dark:light, **: 5°C, 7 day, ***: 0.2% KNO_3

RESULTS AND DISCUSSION

Initial germination percentages of seed lots in all species ranged between 94 and 100%. All pelargonium, gazania, viola and tagetes seed lots had 100 % germination. The difference among the four seed lots in the same species was not significant in any species ($p>0.05$) (Table 2). As well as pelargonium, gazania, zinnia and tagetes seeds had an average germination rate of 100%, it showed a statistically significant difference from other species ($p<0.05$). Antirrhinum, petunia, impatiens, viola, salvia and dahlia seeds had lower germination rates, which varied by species. (Table 2).

Table 2. Initial germination percentages (%) of four seed lots from each flower species.
Çizelge 2. Her çiçek türünden dört tohum lotunun başlangıç çimlenme yüzdeleri (%).

	Lots / Initial germination				
Species	**1**	**2**	**3**	**4**	**Mean**
Dahlia	98	94	94	94	95 ab
Pelargonium	100	100	100	100	100 a
Salvia	95	95	96	95	95 ab
Zinnia	100	98	97	100	99 a
Gazania	100	100	100	100	100 a
Antirrhinum	96	93	93	93	94 b
Viola	100	100	100	100	100 a
Impatiens	100	94	96	98	97 ab
Tagetes	100	100	99	100	100 a
Petunia	95	95	94	94	95 ab

The difference between the averages of the values indicated by different letters in the same column is significant ($p<0.05$).

Mean germination after 24 months at 5°C ranged between 39 and 100% among the species. Pelargonium, zinnia, gazania, and tagetes had germination of 100% and the difference in germination percentages with other species was significant ($p<0.05$). While the difference between the average germination of dahlia and salvia seeds was found to be insignificant ($p>0.05$), the difference between of other species was found to be statistically significant (Table 3).

Decreases in germination after 12 months at 25°C are presented in Table 4. Under these storage conditions, germination percentages ranged between 57 and 100%. While there was no statistically significant difference between viola, impatiens, antirrhinum and petunia seeds, the lowest germination after storage was observed in salvia seeds with 57% and was found to be statistically significant (Table 4). In salvia, lot 1, the lot with lowest germinated had 30% germination, while lot 2 with highest had 78% germination. In a similar manner, lot 3 in dahlia had 59% while lot 1 had 92% germination. Such a variation among the lots was not recorded in the rest of the species.

Table 3. Germination percentages of (%) flower seeds stored at 5°C for 24 months with 6±0.5% seed moisture in hermetic conditions.
Çizelge 3. Hermetik koşullarda 24 ay boyunca 5°C'de, %6±0.5 tohum nemi ile depolanan çiçek tohumlarının çimlenme yüzdeleri (%).

	Lots				
Species	**1**	**2**	**3**	**4**	**Mean**
Dahlia	84	91	86	85	87 c
Pelargonium	100	100	100	100	100 a
Salvia spp.	73	86	96	81	84 c
Zinnia spp.	100	100	100	100	100 a
Gazania spp.	100	100	100	100	100 a
Antirrhinum	34	33	42	45	39 f
Viola	96	92	92	88	92 b
Impatiens	76	73	80	75	76 d
Tagetes	100	100	100	100	100 a
Petunia	88	55	58	61	66 e

The difference between the averages of the values indicated by different letters in the same column is significant ($p < 0.05$).

Table 4. Germination percentages of (%) flower seeds stored at 25 °C for 12 months with 6±0.5% seed moisture in hermetic conditions.
Çizelge 4. Hermetik koşullarda 12 ay boyunca 25°C'de, %6±0.5 tohum nemi ile depolanan çiçek tohumlarının çimlenme yüzdeleri (%).

	Lots				
Species	**1**	**2**	**3**	**4**	**Mean**
Dahlia	92	90	59	78	80 c
Pelargonium	100	100	100	100	100 a
Salvia spp.	30	78	57	61	57 d
Zinnia spp.	98	100	97	99	99 a
Gazania spp.	100	100	100	100	100 a
Antirrhinum	89	83	95	89	89 b
Viola	93	95	96	85	92 b
Impatiens	91	88	88	86	88 b
Tagetes	100	100	100	100	100 a
Petunia	96	88	84	84	91 b

The difference between the averages of the values indicated by different letters in the same column is significant ($p<0.05$).

Figure 1 shows the difference between initial germination and germination after storage at 5°C after 24 months and 25°C after 12 months in relation to the species. Salvia, dahlia and impatiens were significantly higher than the rest of the species between initial and final seed germination ($p<0.05$) while the values of the zinnia, pelargonium, tagetes, gazania, petunia, antirrhinum and viola did not vary significantly ($p>0.05$) at 25°C 12 months storage. Differences were less for storage at 25°C compared to 5°C and were 38% for salvia, 15% for dahlia, 9% for impatiens, 8% for viola, 5% for antirrhinum and 4% for petunia. The difference between initial germination and after storage was the largest for antirrhinum with 55% ($p<0.05$) when seeds are stored at 5°C. The difference was observed as 29% and 21% for petunia and impatiens ($P<0.05$), respectively. While difference in between initial and final germination ($p>0.05$) was not significant for the other species. (Figure 1). In both storage conditions, zinnia, pelargonium, tagetes and gazania seeds had 100% germination after storage.

Results of the present work indicated that seeds of some flower species were found to be more resilient during storage than the others. While zinnia, pelargonium, tagetes and gazania did not lose germinability after storage of 24 months at 5°C and 12 months at 25°C, the germination of antirrhinum, petunia, impatiens, viola, salvia and dahlia seeds decreased at various levels according to species. Genetic factors can affect longevity in crop seeds (Copeland and McDonald 1995; McDonald 1999). In that sense, some flower seeds do not store well due to the genetics of seed deterioration. McDonald (2005) classified flower seed species into three categories according to their storability as short (less than 1 year), medium (less than 3 years) and long (more than 3 years) storable groups. According to this classification, impatiens, viola and salvia are considered as short-term, and antirrhinum, dahlia, pelargonium, petunia and tagetes were considered as medium-term storable species. Our results are in agreement with these findings (Figure 1). Particularly antirrhinum, salvia, petunia and impatiens were found to be sensitive to seed germination loss during storage in our work.

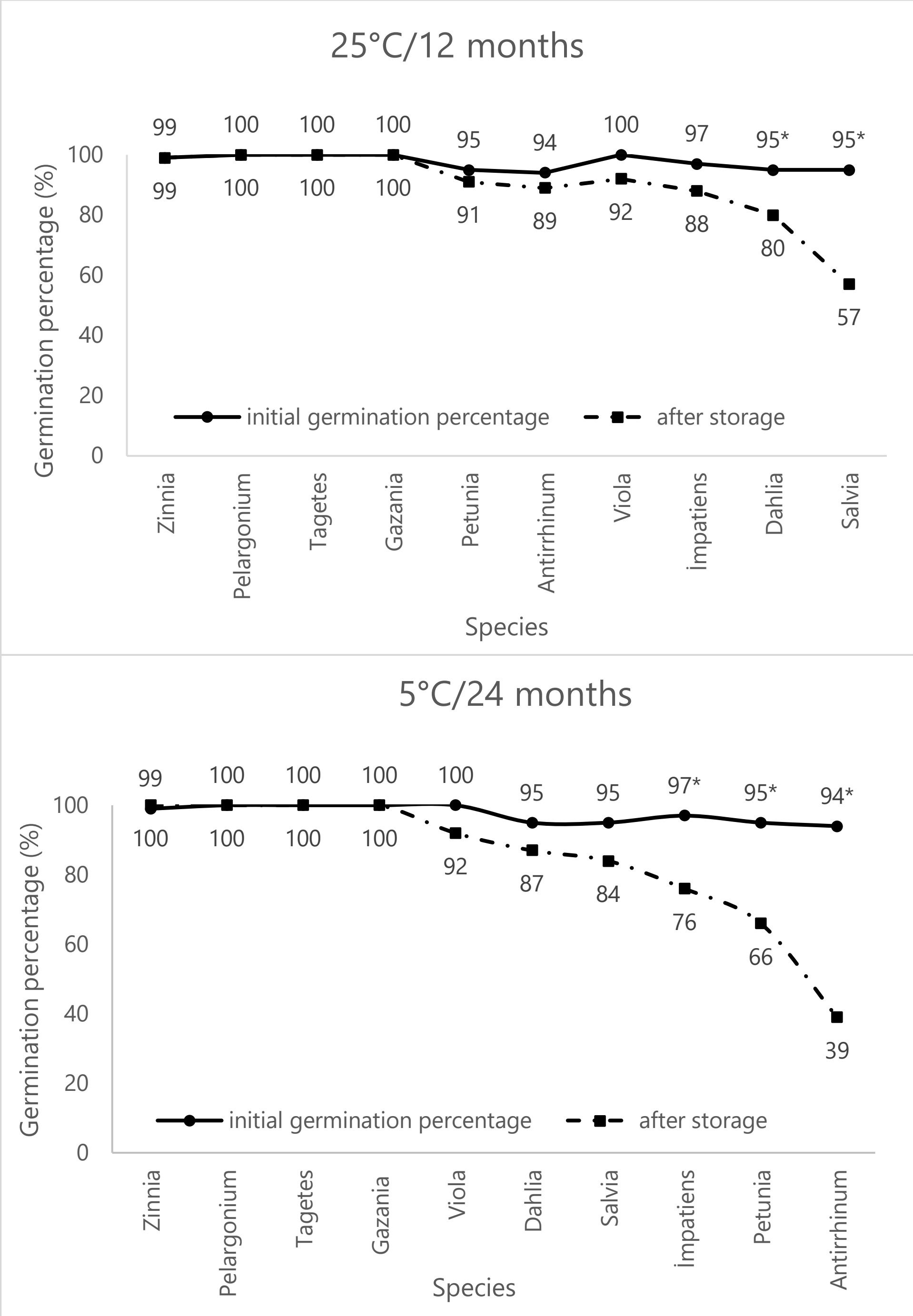

Figure 1. Difference between initial and final seed germination (%) after storage in relation to flower seed species. *: significant at 0.05.
*Şekil 1. Çiçek tohum türlerine göre başlangıç ve depolama sonrası tohum çimlenmesi arasındaki (%) fark. *:0.05 önemlilik*

Seed size can be another important factor in ageing, as small seeds have a greater surface to volume ratio compared with larger seeds. This results in fast water uptake which makes smaller seeds more prone to deterioration. Such an effect can be particularly observed when seeds are stored at certain relative humidity (Carpenter *et al*., 1995a). However, we arranged seed moisture to the very close seed moisture (5.8-6.5%) contents and stored them in hermetic (air and waterproof) packets (Table 1). So, in our study various sized seeds remained at the same moisture content throughout the storage. When seeds are stored at various relative humidities, seeds equilibrate to different seed moisture percentages according to their chemical structure (Justice and Bass, 1978). For example, vinca seeds stored at 5 °C and constant 11, 33, 52, 75 and 95% relative humidity will have a moisture content of 4, 6, 8, 11 and 15 %, respectively (Carpenter and Cornell, 1990). At these relative humidities, seeds of other species such as salvia have different seed moisture contents (Carpenter *et al*., 1995a). This difference in seed moisture may affect longevity.

Some flower seeds such as salvia produce mucilage and polysaccharides around the seed coat. This mucilage attracts water when seeds are stored at high relative humidity, which promotes faster ageing. We observed some mucilage occurrence around the seed during the germination period. This can be one of the reasons for faster ageing in salvia in our work (Figure 1).

Seed chemical structure is also related to ageing (Copeland and McDonalds 1995). In general, seeds with high oil content such as impatiens exhibit shorter storage life. Our work confirmed that impatiens seeds can be considered in the short storable seed category. Loss of germination in impatiens seeds were 21 and 9% after 24 and 12-month storage at 5°C and 25°C, respectively (Figure 1).

Differences in pre-storage maturation level among the seeds are effective on seed longevity (Bewley and Black, 1982). Flower crop seeds produce seeds at various maturation levels due to the inflorescence structures where mature seeds are produced on the bottom and less mature seeds on top of the inflorescence. So, a seed lot contains immature and mature seeds together after once-over harvesting. Then less mature seeds lose germination ability during storage more rapidly than mature ones. We included seed lots with very high initial germination percentages i.e.>94% before storage in all species. So, we aimed to store seed lots that had very high germination level and uniform germination before storage.

The extent of seed ageing affects transplant quality in flower seeds. Fast and rapid seedling emergence is important and valuable in transplant production in bedding plants. The first sign of seed ageing is late and irregular germination which delays healthy and uniform transplant production (Mavi *et al*., 2010). Storing seeds in hermetic, air and waterproof packets is important. Storing seeds in non-hermetic conditions, i.e. open foil packets in high relative humidity, can culminate in rapid seed deterioration in a short period. In general, ideal seed moisture content for flower seeds is proposed as 5-6% (McDonalds, 2005). In our work we stored seeds at around 6% seed moisture and in that sense at the ideal seed moisture for storage. Even though this moisture is ideal, seeds should be retested for germination when they are stored for a period of more than 1 year. Our work shows that such retests are important particularly for some species such as antirrhinum, salvia, petunia and impatiens seeds (Figure 1).

CONCLUSION

Germination percentages during storage among the flower seeds showed a variation. Pelargonium, gazania, zinnia and tagetes seed lots did not lose germination at all while antirrhinum, petunia, impatiens, viola, salvia and dahlia seeds had lower germination rates at various levels. Hermetic storage at low temperature is important for maintaining high germination in flower seeds but our results indicated that particular attention must be paid to antirrhinum, petunia, impatiens, viola, salvia and dahlia seeds.

CONFLICT OF INTEREST

The authors declare that there is no conflict to interests regarding the publication of this article

AUTHORS' CONTRIBUTIONS

İbrahim Demir designed the work, set up the hypothesis, wrote the manuscript, Zeynep Gökdaş did statistical analyses, produced tables and the text, Nazlı İlke Eken Türer find references, improved the manuscript regarding content.

ACKNOWLEDGMENT

This study is based on a project supported by TUBITAK (The Scientific and Technological Research Council of Turkey, Project No:108O381).

REFERENCES

Baskin, C. C., & Baskin, J. M. (2001). *Seeds: ecology, biogeography and evolution of dormancy and germination*. *Nordic Journal of Botany*, *20*(5), 598.

Bewley, J. D., & Black, M. (1982). *Viability, dormancy, and environmental control,* Physiology and Biochemistry of Seeds. Springer-Verlag, New York.

Carpenter, W. J., & Boucher, J. F. (1992). Temperature requirements for the storage and germination of Delphinium x cultorum seed. *HortScience*, *27*(9), 989-992.

Carpenter, W. J., Ostmark, E. R., & Cornell, J. A. (1995a). Evaluation of temperature and moisture content during storage on the germination of flowering annual seed. *HortScience*, *30*(5), 1003-1006.

Carpenter, W. J., Ostmark, E. R. & Cornell, J. A. (1995b). Temperature and seed moisture govern germination and storage of gerbera seed. *HortScience*, *30*(1), 98-101.

Carpenter, W. J., & Cornell, J. A. (1990). Temperature and relative humidity recommendations for storing bedding plant seed. University of Florida Bulletin. 893

Copeland, L. O., & McDonald, M. B. (1995). *Principles of Seed Science and Technology*. Chapman and Hall. New York.

Doijode, S. D. (2001). *Seed Storage of Horticultural Crops*. Haworth Press, Philadelphia.

ISTA. (2016). *International Rules for Seed Testing*. International Seed Testing Association, Bassersdorf, Switzerland.

Justice, O. L., & Bass, L. N. (1978). *Principles and Practices of Seed Storage*. United States Department of Agriculture, Agriculture Handbook 506, Washington DC, USA.

Mavi, K., Demir, I., & Matthews, S. (2010). Mean germination time estimates the relative emergence of seed lots of three cucurbit crops under stress conditions. *Seed Science and Technology*, *38,* 14-25.

McDonalds, M. B. (1999). Seed deterioration: physiology, repair and assessment. *Seed Science and Technology*, *27*, 177-237.

McDonalds, M. B. (2005). *Flower Seed Longevity and Deterioration*. Flower Seeds Biology and Technology, CABI Publishing, UK.

Walters, C. (2015). Orthodoxy, recalcitrance and in-between: describing variation in seed storage characteristics using thresholds responses to water loss. *Planta, 242*, 397-406.