

Seed Aging, Storage and Deterioration: An Irresistible Physiological Phenomenon

Rohit Chhabra*, Shabnam, Tavisha Singh

10.18805/ag.R-1914

ABSTRACT

The need for increased seed quality has become a priority necessary to face the current demand for high standards in the agricultural market. The various factors which contribute to the loss in seed quality, viability, and vigor which can be either physical or physiological. Seed deterioration and aging are considered as a force to reckon the depletion in food reserve, increased fat acidity, increased enzyme activity, and membrane permeability. Quality and viability of seed during storage processes chiefly depends upon the initial status of the seed health and the manner in which it is stored. Achieving appropriate techniques can help to curtail the current agricultural crisis leading to expose of healthy plantlets in the farming sector. This research review attempts to summarize and enlighten the various aspects of seed related features such as viability, aging, and deterioration.

Keywords: Ageing, Deterioration, Irresistible, Physiological, Phenomenon storage

Agricultural Reviews (2019)

INTRODUCTION

Since the discussion of this paper will refer to the seeds which deteriorate with time like any other plant organ age. The process of seed deterioration depends upon physiological status, genetic makeup, and the storage conditions of the seed (Singh and Bassi 2016). The need for an adequate supply of good quality seed is crucial concerning the establishment of a successful seed production program and for the maintenance of viable and fruitful agriculture. Unpredicted losses in seed viability would negatively affect storehouse inventories, production schedule, and seed sale leading to huge losses to agricultural industries every year (Walters *et al.* 2010). The loss of seed health occurs more rapidly as seed moisture content and temperature increases remarkably. Seed storability is generally influenced by seed quality at the time of storage, pre-storage history of seed, (Ellis and Roberts 1977) relative humidity, duration of storage moisture content of the seed, storage temperature, and biotic factors. Seed moisture content and storage conditions are the highlights to control seed storability (Biabani *et al.* 2011). In general, seed deterioration can be defined as the "deteriorative changes occurring with the time that increase the seed's exposure to external challenges and decrease the ability of the seed to survive". Seed deterioration is a complex process associated with numerous physiological alterations including impairment of protein synthesis, lipid peroxidation, DNA damage, and membrane disruption.

The deteriorative biochemical reactions in the seed occur rapidly when the seed moisture content is higher, which imposes a great threat to the survival and longevity of seed progenies (Amjad and Anjum 2002). It is a chain of events marked with different biochemical reactions, mostly membrane damage and impairment of cellular machinery resulting in a reduction of seed (Walters *et al.* 2010) germinability process. Seed deterioration impairs

¹⁻³Department of Botany, Punjab Agricultural University, Ludhiana

Corresponding Author: Rohit Chhabra, Department of Botany, Punjab Agricultural University, Ludhiana, Punjab, India Email: rohit-bot@pau.edu

How to cite this article: Chhabra, R., Shabnam and Singh T. (2019). Seed aging, storage, and deterioration: an irresistible physiological phenomenon. *Agricultural Reviews*, 40(3): 234-238.

Source of support: Nil

Conflict of interest: None

Submitted: 27-06-2019 **Accepted:** 27-08-2019 **Published:** 20-09-2019

the seed phenological and biochemical properties by lowering its quality (Tilebeni and Golpayegani 2011). When seed germinability decreases, it results into decline in the coefficient rate of germination which eventually leads to loss of vigor as result seeds become less viable which may result in the death of seedlings.

SEED STORAGE

Based on the current urge to overcome crisis related to seed storage parameters, it is crucial to preserve them for agriculturally important crops from one season to another. Crucial factors affecting the seed health are the storage temperature and moisture content while, the seed moisture content is generally pre-dominant factor than temperature conditions. Further, the seed potential of several seeds deteriorate during extended storage periods (Abdullah *et al.* 2011), but the deterioration rate greatly varies among the seeds of different species (Roberts 1989). The majority of seeds come into equilibrium when the relative humidity of the environment and their internal moisture content comes together (Abdul-Baki 1980). Seed life is halved for each 1% rise in seed moisture content. It is, therefore, necessary to find out the seed moisture content at the time of purchase and



before and after storage, (Amjad and Anjum 2002) as seed lot quality can deteriorate with time.

Shaban (2013) reported that the storage of any kind of seed at 14% moisture may be possible, while for some other crops, this moisture content is regarded as too high. If the seed moisture is maintained between 5-8%, most of the agricultural crop seeds can be stored for some coming years. Harrington's (1960) rule indicates that the moisture is more than the critical temperature for seed storage. He reported that a one percent reduction in moisture content doubles the shelf life of the seed, but not below 5-6%. A 5.6°C decline in temperature also doubles the shelf life of the seed under storage (Copeland and McDonald, 2001). However, when seed moisture content increases, the temperature is reduced unless the seed is stored in a moisture impervious container. Halder *et al.* (1983) found a significant decrease in the germinability of sunflower seeds when stored under high relative humidity (95%) for twenty days and causes more fast seed deterioration. On the other hand, seed longevity is also reduced under extremely dry conditions of the stored seeds. Dry seeds should be humidified before germination in order to increase the seed moisture content slowly during early stages (Shaban 2013).

Seeds of onion are very difficult to store for a longer time duration as they lose vigor and viability very fast. Low-quality seeds can potentially decrease the speed, and percent germination, seedling emergence and leading to poor crop establishment in the field which results in loss of yield in many crops such as corn, wheat, cotton (Iqbal *et al.* 2002), barley garden pea has been observed (Ghasemi-Golezani *et al.* 2011).

SEED AGING

During seed aging, injury to the cellular organization might represent an important factor in explaining seed deterioration which negatively affects seed properties. There is a decline in the activity of enzymes like catalase (CAT), superoxide dismutase (SOD), glutathione reductase (GR) and peroxidase (POX) during seed deterioration and aging. The inactivation of proteins during seed storage may (Dahuja and Yadav 2015) lead to seed deterioration as it reduces the metabolic ability of the cell to repair the damages caused during aging. The protein inactivation may occur by losing or gaining of functional groups or by interconversion of amino acids within the protein structure. The primary cause of the loss of viability in seeds is the result of the weakening of cellular membrane and integrity at an early phase during the seed storage. As a result, seed cells cannot hold their regular physical state and cannot perform a metabolic function. The weakening of membrane generally increases electrolyte leakage that results in loss of field emergence and seed germination. The rate of seed deterioration is greatly influenced by the environmental factors like temperature, relative humidity or moisture content. The kind/variety of seed and seeds initial quality also leads to seed deterioration. Biological factors viz., fungi, pests, mites, insects and pathogen attack may include

also the seed biochemical machinery and induces damage. Improper handling and packaging during storage also lead to seed deterioration.

It was also found that when seeds of *Pyrus* were stored at ambient temperature rather than storing at a temperature of 4°C from 6–12 months, the percent germination clearly decreased. The seed death is ultimately caused due to the accumulation of cellular constituents and secondary metabolites resulting from oxidative damage (Bailly 2004). Loycrajjou *et al.* (2008) studied that during aging, seed deterioration is induced which may lead to a higher amount of protein oxidation which may induce the greater loss of functional properties of protein and enzymes. Scialabba *et al.*, (2002) recorded that the activity of SOD decreased in aged seeds as compared to the fresh seeds of radish. Pallavi *et al.* (2003) reported the sharp decline in the enzymatic activity of POX during aging of sunflower seeds.

PHYSIOLOGICAL AND BIOCHEMICAL CHANGES

Seed deterioration is a combined process associated with various cellular, metabolic and chemical alterations which include lipid peroxidation mediated by free radicals, decrease in protein content, inactivation of enzymes of protein biosynthesis, breakdown of cell wall, impairment of RNA (Mahjabin *et al.*, 2015). Lipid peroxidation is the results of denaturalization of DNA which prevents protein transcription, translation and causing oxidation of many amino acids. These types of damages occurring in the seed testa decrease the rate of seed germination. As the membrane is lipid bilayer in nature, it is the major site for the process of lipid peroxidation. Free radicals, lipid peroxidation and ROS (Hendry 1993) scavenging enzymes are widely considered to be the major contributors of seed deterioration. They also change the unsaturated fatty acid composition, which affects the lipid bilayer nature of cell membranes and increase the permeability of membranes by inactivating membrane-bound proteins. A gradual increase in the amount of total soluble sugars in the leachate content was found with the increase in seed deterioration. However, the increase in leaching of sugars was due to the lack of their utilization (Abdul-Baki and Anderson (1973) due to the low viability or increased with subsequent increase in storage period irrespective of genotypes in the soybean crop. Extensive leakage of sugars may signify a loss of respirable substrate from deteriorated seeds.

Deterioration is mainly due to the indirect or direct action of (reactive oxygen species) ROS, affecting the numerous metabolic processes such as respiration, CO₂ fixation, and gaseous exchange. The extensive generation of reactive oxygen species, such as the hydrogen peroxide (H₂O₂), superoxide radical (O₂) and the hydroxyl radical (OH) may impede seed damage. These biochemical reactions lead to the oxidative changes in the cell (Moller *et al.* 2007) and increase the chances of mutation rate. The cells consist of a complex defense system to protect against the

damage caused during the process of seed deterioration. The defense mechanism is composed of numerous non-enzymatic and enzymatic mechanisms including catalase, superoxide dismutase, peroxidase, and ascorbate peroxidase — antioxidant enzymes which catalyzes the regeneration and formation reactions to scavenge the reactive oxygen species (ROS). Demirkaya *et al.* (2010) reported a greater degree of association between the loss of seed viability and the lower activity of catalase in the seeds of onion. The decrease in catalase activity is thus correlated with the decline in the seed viability and also indicates its poor affinity for H_2O_2 (Gutteridge and Halliwell 1990). Changes in these enzymatic activities are very important biomarkers in monitoring the biochemical changes resulting from deteriorative processes (Silva *et al.* 2016).

Techniques related to biochemical aspects have also been employed to assess seed quality to determine the activity of enzymes involved in cell respiration (Silva *et al.* 2016) and reserve mobilization. The decline in activity of an enzyme in the seed lowers the respiratory capability, thus leading to a decrease in the energy and assimilate supply of the germinating seeds. Rapidly deteriorating seeds are related to damages caused at the membrane, protein levels, and nucleic acids. Peroxidation of unsaturated fatty acids is regarded as one of the major reasons for the loss of seed longevity and viability. Auto oxidation of lipids and rise in the content of free fatty acids during storage duration are regarded as the major reason for rapid seed deterioration. During autooxidation, spontaneous oxidization of fatty acid hydrocarbon chains takes place in the presence of oxygen which thus (Taiz and Zeiger 2006) leads to produce reactive free radical intermediates well known as hydroperoxides (Dahuja and Yadav 2015).

Seeds may accumulate damage during storage, and the degree of deterioration varies through the stress imposed by ROS generation. Analysis of the degree of damage might predict germination performance of a seed lot. Mitochondria are known to be among the primary sites of deterioration during seed aging. When mitochondria become non-functional, initiation of anaerobic respiration is expected to deliver the energy for metabolic processes at least for repair. Indeed, a relation between ethanol production and seed deterioration is evidenced by several workers (Perry 1978); (Taylor *et al.* 1999); (Rutzke *et al.* 2008). In those studies, seed deterioration induces ethanol production which was measured using immobilized enzyme technology, laser-based photoacoustic spectroscopy, and gas chromatography.

POST-HARVEST DETERIORATION

It includes processing machinery, threshing, handling, seed collection, drying, and transporting. Mechanical injury to the seeds during storage is one of the most vital causes of seed deterioration. Very dry seeds are prone to this kind of mechanical injuries. Such injuries result in physical damage or fracturing of the seed coat and rupturing essential seed

parts. Damaged seed coats usually allow early penetration and easy access to various pathogens; thus, making the seed susceptible to microbial attack. Physical seed damage is exhibited during severe mechanical damage by cotyledonsplit, shattered, and broken seeds parts. Large seeded crops are highly prone to mechanical damage than small-seeded plants.

SEED DETERIORATION SYMPTOMS

Seed deterioration is an irreversible, inexorable, and degenerative change in the seed quality. It can be observed in its dropped performance during germination viz., delayed seedling emergence, lesser root/shoot growth, impaired vigor index and loss of the capacity to germinate. Changes in seed coat color are apparently due to oxidative reactions occurring in the seed coat which are enhanced under high temperature and other stress-related conditions.

Abnormal seedlings, lower yield with decreased storability and crop uniformity are the major changes which lead to loss of germinability and field emergence. Through electron microscopy and SEM studies (Silva *et al.* 2015), two broad patterns of plasmalemma extraction from the cell wall and coalescence of lipid bodies was observed in relation to seed deterioration. Both of these events mainly influence cell wall properties. Some of the main consequences of membrane damage are: Breaks in the plasmalemma structure and its contraction from the cell wall, lack of dicytosomes, lysosome lysis, Fragmented endoplasmic reticulum lacking polyribosomes, mitochondria and plastid dis-integration, Monosomesdispersal in the cell sap, Coalescence of lipid particles and Condensation of chromatin and nucleus (Mahajbin *et al.* 2015).

ORGANISMS ASSOCIATED WITH SEEDS

Organisms associated with seeds during storage are bacteria, fungus, mites, rodents, and insects. The microbial activity can cause damage which results in loss of vigor, viability, and complete loss of seed material. There are various factors such as temperature, a pre-storage infection which may promote fungal infection and infestation. Most of the fungus belongs to genus *Penicillium* and *Aspergillus*. They promote seed deterioration by secreting toxic metabolites which destroy the seed cells. Mechanically damaged seed allows easy and quick access to various pathogens to penetrate the seed. Seeds have to be stored at low moisture content, low temperature to minimize the risk of fungi invasion. Researchers reported that all storage fungi are completely inactive below 62% RH and show very little activity below 75% RH. In general, the amount of fungi in a seed often shows an exponential relationship with RH. The storage bacteria require a minimum of 90% relative humidity for growth and can only become significant under conditions where fungi are already growing (Shelar *et al.* 2008).



TESTS FOR DETERMINING SEED VIABILITY

The most sensitive tests used for detecting early seed deterioration is glutamic acid decarboxylase activity test and tetrazolium (TZ). TZ test is mostly regarded as a quick method to estimate seed viability. This test distinguishes between the dead and viable embryonic tissues based on their relative respiration rate in the hydrated state. The cell membranes become more water permeable and allow the cell contents to leak into the water and thus increasing electrical conductivity. Increase in leachate content of seeds when soaked in distilled water is a characteristic symptom of non-viable seeds. The accumulation of free fatty acids concludes in a decline of cellular pH and is detrimental to normal cellular metabolism. Enzyme Activity Tests are used to measure the activity of enzymes like, lipase, diastase, amylase, catalase, dehydrogenase and peroxidase of imbibed seeds as an indicator of seed viability. Other testing methods include hydrogen peroxide test, free fatty acid test, indoxyl acetate test, excised embryo test, ferric chloride test, fast green test, X-ray test, and sodium hypochlorite test.

OILY SEEDS

Seeds rich in lipids have limited longevity due to their specific biochemical composition. Fatty acids are the most important factor that determines the susceptibility of oil to photo-oxidation. During oily seed storage (Morello *et al.*, 2004), a decline in the total oil content and percent seed germination was observed. Protein content, fatty acid composition, and oil content are regarded as the most important quality parameter of oily seeds. For example, seeds of sunflower need special care during storage due to higher oil content (Shaban 2013).

USE OF ZEOLITE DRYING BEADS FOR SEED STORAGE

Seeds stored with high moisture content commonly demonstrates a higher respiration rate and increased fungal attack resulting in increased seed deterioration. Thus, for successful storage of seeds, zeolite drying beads is a newly developed desiccant technology in which the seeds can be dried efficiently to secure storage moisture contents and preserving seeds in moisture impervious containers. This technique not only helps to maintain low moisture contents but also prevents losses against the damage caused by mites, rodents and insects. It is a simple, inexpensive, and reusable method of seed storage. Drying beads are made up of ceramic materials with absorbing and water holding capacity in their microscopic pores. The beads continue to take up water until all of its pores are filled, up to 20–25% of their initial mass and creating a very little humid environment. Seeds, when placed into a container with the beads at low RH, will lose water and will continue to do so until they reach equilibrium. The beads can be removed and regenerated individually by heating at

a temperature greater than 200°C for 2 hours to release the soaked water afterward (Walters *et al.*, 2010).

CONCLUSION

In agricultural crops, the seed germination parameters and subsequent seedling emergence or establishment are greatly influenced by different environmental factors in the field. The increment decline in germination rate index, vigor index, and seed quality will eventually result in delayed seedling emergence, flowering, and maturity, followed by an adverse decline in growth and yield ratio. Therefore, it is necessary to carry out preventive measures for improving seed quality and health conditions by ameliorating seed deterioration. Improving storage conditions could help prolong the seed longevity.

REFERENCES

- Abdul Baki, A. and Anderson, J. D. (1973). Vigour determination in soyabean seeds by multiple criteria. *Crop Sci* 13: 630-633.
- Abdul-Baki, A. A. (1980). Biochemical aspects of seed vigour. *Hort Sci* 15:765-771.
- Abdullah, M. A., Abdullah, A. A., Safwat, O. K., Mohmoud, A. W. A., Mahran, El. N., Abdullah, A. I. (2011). Influence of storage conditions on seed quality and longevity of Four Vegetable Crops. *Am-Euras J Agric Environ Sci* 11: 353-59.
- Amjad, M. and Anjum. M. A. (2002). Effect of relative humidity and aging period on the quality of onion seed. *Int J Agri Biol* 2: 291-296.
- Bailly, C. (2004). Active oxygen species and antioxidants in seed biology. *Seed Sci Res* 14: 93–107.
- Biabani, A., Boggs, L.C., Katozi, M., Sabouri, H. (2011). Effects of seed deterioration and inoculation with Meso rhizobium ciceri on yield and plant performance of chickpea. *Aust J Crop Sci* 5:66-70.
- Copeland, L. O. and McDonald, M. B. (2001). Principles of Seed Science and Technology, Kluwer academic publishers, Boston, Pp. 330.
- Dahuja, A. and Yadav, S. (2015). Biochemical basis of seed deterioration-an overview. *Seed Res* 43:1-8.
- Demirkaya, M., Dietz, K. J. and Sivritepe, H. O. (2010). Change in antioxidant enzymes during aging of onion seeds. *Not Bot Hort Agrobot Cluj* 38: 49-52.
- Ellis, R. H. and Roberts, E. H. (1977). A revised seed viability monograph for onion. *Seed Res* 5:93-103.
- Ghasemi-Golezani, K. Sheikhzadeh-Mosaddegh, P. Shakiba, M. R. Mohamadi, A. and Nasrollahzadeh, S. (2011). Development of Seed Physiological Quality in Winter Oilseed Rape (*Brassica napus*L.) Cultivars. *Not Bot Hort Agrobot Cluj* 39:208-212.
- Gutteridge, J. M. C. and Halliwell, B. (1990). The measurement and mechanism of lipid peroxidation in biological systems. *Trends Biochem Sci* 15: 129-135.
- Halder, S., Kole, S. and Gupta, K. (1983). On the mechanism of sunflower seed deterioration under two different types of accelerated aging. *Seed Sci Technol* 11: 331-339.
- Harrington, J. F. (1960). Preliminary report on the relative desirability

- of different containers for storage of several kinds of vegetable seed. Calif Univ Dept Veg Crops Ser 104-108.
- Hendry, G. A. F. (1993). Oxygen free radical processes and seed longevity. *Seed Sci Res* 3:141-153.
- Iqbal, N., Basra, S. H. M. A. and Rehman, K. (2002). Evaluation of vigour and oil quality in cottonseed during accelerated aging. *Int J Agri Biol* 4:318-322.
- Loycrajjou, L. Y., Steven, P. C., Groot, B. M., Job, C. and Job, D. (2008). Proteome wide characterization of seed aging in Arabidopsis. A comparison between artificial and natural aging. *Prot Plant Physiol* 148:620-641.
- Mahjabin., Bilal, S., and Abidi, A. B. (2015). Physiological and biochemical changes during seed deterioration: A Review. *Int J Recent Sci Res* 6:3416-3422.
- Moller, I. M., Jensen, P. E. and Hansson, A. (2007). Oxidative Modifications to cellular components in plants. *Ann Rev Plant Biol* 58: 459-468.
- Morello, J. R., Motilva, M. J., Tovar, M. J. and Romero, M. P. (2004). Changes in commercial virgin olive oil (CV Arbequina) during storage with special emphasis on the phenolic fraction. *J Food Chem* 85: 357-364.
- Pallavi, M., Sudheer, S. K., Dangi, K. S. and Reddy, A. V. (2003). Effect of seed aging on physiological, biochemical and yield attributes in sunflower (*Helianthus annuus* L.) cv. Morden. *Seed Res* 31: 161-168.
- Perry, D.A. (1978). Report on the vigour test committee 1974-1977. *Seed Sci Technol* 6:159-181.
- Singh, R. and Bassi, G. (2016). Response of bittergourd (*Momordica charantia* L.) seed to seed priming treatments under sub-optimal environments. *Ind J Agri Sci* 86 (7): 935-939.
- Roberts, E. H. (1989). Seed storage for genetic conservation. *Plant Today* 2: 12-18.
- Rutzke, C.F.J., Taylor, A.G. and Obendorf, R.L. (2008). Influence of aging, oxygen, and moisture on ethanol production from cabbage seeds. *J American Soc Hort Sci* 133:158-164.
- Scialabba, A., Bellani, L. M. and Dell'aquila, A. (2002). Effects of aging on peroxidase activity and localization in radish (*Raphanus sativus* L.) seeds. *Eur J Histo Chem* 46:351-358.
- Shaban, M. (2013). Review on physiological aspects of seed deterioration. *Int J Agri Crop Sci* 6: 627-631.
- Shelar, V. R., Shaikh, R. S. and Nikam, A. S. (2008). Soybean seed quality during storage: A review. *Agric Rev* 29: 125-31.
- Silva, M. I. L., Voigt, E. L., Grangeiro, L. C., Cunha, E. E., MacEdo, C. E. C. and Torres, S. B. (2015). Determination of harvest maturity in *Capsicum baccatum* L. seeds using physiological and biochemical markers. *Aust J Crop Sci* 9:1010-1015.
- Silva, P. P., Sekita, M. C., Dias, D. C. F. and Nascimento, W. M. (2016). Biochemical and physiological analysis in carrot seeds from different orders of umbels. *Revista Ciência Agronômica* 47:407-413.
- Stumof, C. L., Peske, S. T. and Baudet, L. (1997). Storage potential of onion seeds hermetically packed at low moisture content. *Seed Sci Technol* 25:25.
- Taiz, L. and Zeiger, E. (2006). Energy and Enzymes. In: TAIZ, L.; ZEIGER, E. *Plant Physiology*. 4th ed. Sunderland: Sinauer Associates 2: 1-22.
- Taylor, A.G., Johnson, C.F. and Kataki, P.K. (1999). Ethanol production by hydrated seeds: A high resolution index of seeds quality. *ISHS Acta Horticulturae* 504:153-157.
- Tilebeni, G. H. and Golpayegani, A. (2011). Effect of seed aging on physiological and biochemical changes in rice seed (*Oryza sativa* L.). *Int J Agri Sci* 1:38-143.
- Walters, C., Ballesteros, D. and Vertucci, V. A. (2010). "Structural mechanics of seed deterioration: Standing the test of time". *Plant Sci* 179: 565-573.

