

Physiological characteristics of crops affected by seed deterioration

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ABSTRACT: Crop seeds are main and primary inputs of agriculture that determined safety and amount of crop production in agricultural fields. The deterioration of the stored seed is a natural phenomenon and the seeds tend to lose viability even under ideal storage conditions. Accelerated ageing has been recognized as a good predictor of the storability of seed lots. Aged seeds show decreased vigour and produce weak seedlings that are unable to survive once reintroduced into a habitat. The characteristics of the chemical composition of oil crops (soybean and sunflower) are related to specific processes occurring in seed during storage. Lipid auto-oxidation and increase of free fatty acid content during storage are the most often mentioned reasons for accelerated damage of seed of oily plant species. Vigor testing becomes more important in seeds stored under unknown or adverse storage conditions. By identification of seed ageing reasons, we can avoid from its negative effects using protect instructions.

Key words: Acid, ageing, Crop, seed, ageing

INTRODUCTION

Seed ageing is associated with various alterations including loss of membrane integrity, reduced energy metabolism, impairment of RNA and protein synthesis, and DNA degradation (Kibinza et al., 2006). During storage, a number of physiological and physicochemical changes occur, termed aging (Sisman, 2005). The rate at which the seed aging process takes place depends on the ability of seed to resist degradation changes and protection mechanisms, which are specific for each plant species (Sisman and Delibas, 2004; Mohammadi et al., 2011). The main external factors causing seed damage during storage are the temperature, relative air humidity and oxygen. Possibility to regulate these factors makes the basis for longer seed storage.

Seed deterioration is inexorable and the best that can be done is to control its rate. Many factors contribute to the predisposition for seed deterioration. These include genetics where certain seeds are inherently longer lived than others. Seed structure can also influence seed deterioration. Simple differences in seed size can mean that smaller seeds with a greater surface area to volume ratio are more exposed to uptake of water that would make them prone to deterioration more than larger seeds.

Seed chemistry influences the amount of free water available to seeds that increase deterioration rate. Seeds that possess mucilage around their seed coats such as *Salvia* under high relative humidity environments would be more likely to transfer that moisture into the seed causing more rapid deterioration. It has been known for a long time that a progressive fragmentation of embryonic nuclear DNA occurs during seed ageing (Cheah and Osborne, 1978). DNA damage can be due to an uncontrolled degradation following extensive DNA oxidation or to DNA laddering, as is commonly observed in active and genetically controlled programmed cell death (PCD) (Stein and Hansen, 1999). ROS have been widely cited as being the main factor causing seed ageing during their prolonged storage (Priestley, 1986).

Deterioration in different tissues and seeds seed is a composite of tissues that differ in their chemistry and proximity to the external environment. Thus, it should not be assumed that seed deterioration occurs uniformly throughout the seed. Perhaps the best example that this does not occur comes from the use of the tetrazolium chloride (TZ) test where living tissues in a seed turn red when exposed to the compound. When studies have been conducted on seeds using controlled natural and artificial aging conditions, differences in the deterioration of seed tissues have been observed.

In dicot seeds such as soybean, the embryonic axis is more sensitive to deterioration than the cotyledons. Embryonic axes possess more MDA and total peroxides which are markers of greater free radical presence in the axes compared to aged cotyledons. Thus, embryonic axis is more prone to aging in monocot and dicot seeds and, of the axis structures, the radicle axis is more sensitive to deterioration than the shoot axis.

Ageing in various seeds

A fatty acid composition is the most important factor which determines oils susceptibility to oxidation (Morello et al., 2004). Quality parameters of seed such as oil content, fatty acid composition and protein content are significantly influenced by storage conditions and time (Ghasemnezhad and Honermeier 2007). For example, sunflower seed storage demands special care due to high oil content which can easily provoke processes that can lead to loss of germination and viability.

For short term storage the seed may be kept in storage facilities that are dry and relatively cold, in order to preserve biological value of seed. These facilities have no special temperature and humidity control. For longer and more reliable seed storage, facilities with specific climate control should be used. Depending on temperature coefficient the plant species display different reaction to storage longevity at a constant storage temperature of 10°C. Onion seed showed the lowest temperature coefficient, and it proved to be hard for storing, and the barley seed showed the highest temperature coefficient, and it maintained its germinability under various conditions (Milošević et al., 1996). Seed moisture content is the most important determinant of longevity in storage. The important thing from the perspective of chemical reactions in the seed is water activity, which means the chemical potential of water in the system (Basra, 1984). Storage of one kind of seed at 14% moisture may be feasible, while for a different species 14% moisture might be too high. Seed of the majority of agricultural plant species may be stored for several years provided that the seed moisture is maintained between 5-8%. The seed moisture content depends on relative air humidity in the seed storage facility. Higher air humidity increases seed moisture content, leading to more rapid seed deterioration, particularly at the moisture content above 12%. Seed with 70% of germination will generally not store as well as another one with 95% of germination. But it is apparent that some important aspects of seed storability and vigour may not be reflected in the initial germination percent prior to storage. A high initial germination provides no assurance that the lot will store as well as another lot of the same kind with the same or even lower germination. The solution to problems to the storability of seed lies in the development of

tests that will differentiate among seed lots with respect to storage potential. Seed vigour declines first as seed deteriorates, followed by loss of germination and viability.

In the majority of plant species having oil rich seeds the lipids that are at risk of auto-oxidation of fatty acid chain. Decrease of linoleic acid content in aged seed was highly pronounced in maize lines with higher oil content (Balešević- Tubić et al., 2004).

It is believed that biochemical processes of lipid peroxidation are the major cause of seed deterioration during storage. Lipid peroxidation and products resulting from these processes lead to DNA denaturation, prevent translation and protein transcription, and cause oxidation of the most reactive amino acids (Popović et al., 2006). When these types of damages occur in seed, they may cause decrease in vigour and seed germination. Mechanism of oxidative damage is very complex and occurs as two different types of fatty acid changes. The first one is linked to the process of aging during the first week of storage and includes spontaneous oxidation of unsaturated fatty acids, with no changes occurring in saturated fatty acids. In the second type of damage the seed that has lost its ability to germinate showed oxidation of both saturated and unsaturated fatty acids. Activity of free radicals in seed may depend on water content, seed components (for example the whole seed, cotyledon, embryo), seed lot, species and variety, as well as the aging treatment (Laloi et al., 2004). Peroxidative changes in fatty acid composition of membrane lipids exert influence on viscosity, permeability and membrane cell function. Also, decrease in mitochondrial respiration during storage could be associated with peroxidative changes in lipid mitochondria that lead to loss of seed vigour (Ferguson et al., 1990). Final product of lipid peroxidation is lipid hydroperoxid (ROOH) from which aldehydes are formed, including malonyl-dialdehyde (MDA). Determination of MDA content is the conventional method used for determination of lipid peroxidation (Sung and Jeng, 1994).

Deterioration of seeds

Degradation and inactivation of enzymes due to changes in their macromolecular structures is one of the most important hypotheses proposed regarding causes of ageing in seeds (Bailly, 2004; Basavarajappa et al., 1991; Basra and Malik, 1994; Goel et al., 2002; Kalpana and Rao, 1993; Lehner et al., 2008; McDonald, 2004; Salama and Pearce, 1993).

Most of these studies suggest that decreases occur in the activity of enzymes such as superoxide dismutase, catalase, peroxidase and glutathione reductase in aged seeds. The general decrease in enzyme activity in the seed lowers the respiratory capacity, which in turn lowers both the energy (ATP) and assimilates supply of the germinating seed. Therefore, several changes in the enzyme macromolecular structure may contribute to their lowered germination efficiency. As evidence mounts, the leading candidate causing seed deterioration increasingly appears to be free radical production. Free radical production, primarily initiated by oxygen, has been related to the peroxidation of lipids and other essential compounds found in cells. This causes a host of undesirable events to include decreased lipid content. Lipid peroxidation begins with the generation of a free radical (an atom or a molecule with an unpaired electron) either by autoxidation or enzymatically by oxidative enzymes such as lipoxygenase present in many seeds.

One of the major sources of ROS in metabolically active seeds is the mitochondrial respiratory chain (Bailly, 2004). Lipid peroxidation occurs in all cells, but in fully imbibed cells, water acts as a buffer between the autoxidatively-generated free radicals and the target macromolecules, thereby reducing damage. Thus, as seed moisture content is lowered, autoxidation is more common and is accelerated by high temperatures and increased oxygen concentrations. Lipid autoxidation may be the primary cause of seed deterioration at moisture contents below 6%. Above 14% moisture content, lipid peroxidation may again be stimulated by the activity of hydrolytic oxidative enzymes such as

lipooxygenase, becoming more active with increasing water content. Between 6 and 14% moisture content, lipid peroxidation is likely at a minimum because sufficient water is available to serve as a buffer against autoxidatively generated free radical attack, but not enough water is present to activate lipooxygenase-mediated free radical production.

The relationship between seed deterioration and the enzymes involved in lipid peroxidation, free radical removal, and seed respiratory metabolism also has been studied (Shen and Odén, 1999). All enzyme activity is positively correlated with germination of seed as ageing progressed germination also decreased and enzyme activity also decreased which showed significant deterioration in both accelerated as well as in natural aged seed lot. All seeds undergo aging process during long-term storage which leads to deterioration in seed quality, especially in the humid tropical regions. However, the rate of seed deterioration can vary among various plant species (Merritt et al. 2003). Aged seeds show decreased vigour and produce weak seedlings that are unable to survive once reintroduced into a habitat (Atici et al. 2007). Some protective mechanisms involving free radical and peroxide scavenging enzymes,

such as catalase (CAT), peroxidase (POD) and superoxide dismutase (SOD) have been evaluated within the mechanism of seed aging (Hsu et al. 2003, Goel et al. 2003, Pukacka and Ratajczak 2007), Loycrajjou et al. (2008) reported that ageing induced deterioration increase the extent of protein oxidation thus inducing loss of functional properties of proteins and enzymes. Scialabba et al. (2002) reported that peroxidase activity decreased in aged seeds as compare to fresh seeds in radish. Pallavi et al. (2003) studied that sharp decline in peroxidase enzyme during ageing in sunflower.

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