Seed storage

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Plants use seeds and pollen to spread their genes in time and space. In the course of evolution plants have developed mechanism to tolerate desiccation of their pollen or seed in the dispersal phase. Although not all plants produces desiccation tolerant seeds, it is the case for most of our crops. Seeds that do not tolerate desiccation are called recalcitrant seeds. Examples of recalcitrant seeds are those from oaks or mangroves. The advantage of desiccation tolerant seeds is that they can be stored, transported and survive for some time. The period of survival varies between different crops. The world record for survival is for date palm seeds. The seeds were excavated in the dessert in Israel and radiocarbon dating showed them to be about two thousand years old. Seeds that were put in the soil germinated and gave a healthy date palm. Longevity, storability and shelf life are words used to describe the relative ability of seeds to survive storage, either on the shelf or buried in the soil.

Factors influencing shelf life

During seed storage damage to the seed is gradually accumulating. In a dry condition this damage cannot be repaired because repair enzymes need a minimal moisture level for their activity. When the damage is limited only a delay in germination or emergence will be noted. More damage will result in an increasing frequency of abnormal seedlings and eventually the frequency of emerging plants will drop. The rate of seed deterioration depends on multiple factors:

1. First there is variation between species and even within crops. The latter provides potential in breeding programs.
2. Second there is the quality of the seed at the time of dispersal or harvest. When seeds are harvested before full maturation the shelf life will be less.
3. A third factor is the treatments given to the seeds between harvest and storage. It is well known that seed priming can results in a considerable shortening of the storability.
4. The fourth important factor concerns the storage condition: temperature, moisture and oxygen. The higher the level of these the faster the seeds will deteriorate.

In the past some general rules have been developed. The ‘James rule’ tells that for a reasonable shelf life the sum of temperature in degrees Fahrenheit and the Relative humidity (%RH) should not exceed 100, or the temperature in degrees Celsius and the %RH should not exceed 60. The ‘Herrington’s rule’ states that seed longevity decreases by one-half for every 1% increase in moisture content or every 10°F (6°C) increase in temperature. Prof. Kent Bradford has added the ‘Metronome’ rule stating that a seed has a maximum number of ‘clicks’. Once the ‘clicks’ run out deterioration increases. The latter is related to observations in practice that the ability for seed emergence does not drop gradually during storage, but most often sets in only after some time to drop thereafter. The most important rule is economics and to consider the type of seeds you are storing and the costs for storage. Barley seeds have generally a long shelf life and the seeds themselves are bulky and not expensive. Primed celery, however, have a rather poor shelf life (a few weeks), are relative expensive and volumes are not large. As a consequence primed celery seeds will be stored under more protective conditions compared to barley seeds.

Moisture content and water activity

Moisture has a strong effect on the rate of seed deterioration. In the seed industry the seed moisture levels is often provided as ‘moisture content’, which is the fraction (percentage) of water in the seed. Mostly this is on fresh weight basis. For the relative more expensive horticultural crops both temperature and relative humidity are controlled in the warehouses. Seeds that are stored in the warehouse will get in equilibrium with the relative humidity. As oil bodies in the seed cannot contain water, the seed moisture content of oily seeds in the warehouse will be lower compared to that of starchy seeds, although for both seeds the moisture level in the cytoplasm of will similar.

The food industry more often uses the term water activity. In principle food without water has a water activity of 0%, while food in equilibrium with 100% RH has a water activity of 1.0 and food stored at 50% RH will get equilibrated at a water activity of 0.5. In equivalence with this, seeds of different crops stored in a warehouse at 30% RH will all equilibrate at a water activity of 0.30.

Since seed deterioration is faster at an higher water activity or seed moisture level, one would expect slower deterioration under more dry conditions. That is indeed the case, but under ultra-dry conditions (below 10 or 15% RH) deterioration may be faster again, although contrasting observations have been made. When seeds were stored ultra-dry in a container which is opened every three months, those seeds had aged faster compared to seeds stored under similar conditions at a slightly higher RH. But when seeds were stored ultra-dry in hermetically closed pouches, the ageing rate was comparable to storage under slightly higher seed moisture levels, not faster and not slower. From food science it is known that lipid oxidation is faster under ultra-dry conditions and it is likely that in the presence of oxygen, the oxidation of the membrane lipids is accelerated upon ultra-dry seed storage.

Economics of seed storage

When storing seeds it is important to consider benefits and costs of creating optimal storage conditions. For genebanks it is essential to keep the seeds alive for decades and consequently the Centre for Genetic Resources Netherland stores their seeds hermetically sealed at -20 °C after drying at 15% RH. Horticultural seeds are often stored at 30% RH and 15 or 20 °C in 'open' storage, whereas storage of relative cheap agricultural seeds is often less controlled. The seed water activity has the largest effect on shelf life. Drying is therefore the first thing to do, but seeds are hygroscopic and will reabsorb moisture upon 'open' storage. In temperate regions, it is not too expensive to store seeds at temperatures around 15 or 20 °C, but in the (sub)tropics warehouses cooling requires much energy. Moreover it should be considered that cooling of air results in a higher relative humidity. If the capacity of dehumidifiers is not enough, it can be counterproductive to cool the warehouse.

The effect of oxygen

Except for damage by insects and micro-organisms all deterioration during seed storage is related to oxidation by 'free radicles'. Anti-oxidants are therefore the main defence for seeds to maintain viable. Fresh seeds contain high levels of vitamin E, which is needed to prevent oxidation of the cell and mitochondrial membranes. Oxygen is one of the largest sources of 'free radicles' during dry seed storage. Therefore a third option to prolong shelf life of seeds is the use of storage under low oxygen levels or even anoxia. That method is widely used by the food industry, e.g. to maintain quality of coffee beans or nuts, but at present less used with seeds for propagation. The importance here is to use packaging material that is not or hardly permeable to oxygen. Most plastics are often permeable to oxygen. For consumer packages metal containers or laminated aluminium foil pouches will do a perfect job. For bulk storage other material is needed, e.g. laminated liners fromh special plastics. Bulk storage in oxygen-proof big bags has also the advantage of keeping the moisture level stable. Especially for tropical regions low oxygen storage may economically be a good alternative for high investments in temperature and humidity controlled warehouses. Moreover, in the tropics seed quality loss during storage at the dealers should not be underestimated.

Model for temperature and moisture effect

A mathematical model has been developed by Ellis and Roberts to estimate the ageing effect of moisture and temperature. This model contains species-specific constants describing their sensitivity to these factors. These species specific constants have been determined for a large number of crops using artificial storage conditions. Although the value of the model and species specific constants is debated, especially regarding long term storage in gene banks, the model can be very useful in calculating the relative effect of changes in the seed moisture level or storage temperature on the shelf life of a seed lot. A web based application of the model can be found on the web sites: http://data.kew.org/sid/viability/ and http://data.kew.org/sid/viability/final_percent.jsp. The model uses seed moisture content as input, whereas for controlled seed storage the warehouse RH is the point of control. To calculate seed moisture content based on the equilibrium RH, the web site offers a tool at http://data.kew.org/sid/viability/mc1.jsp?constid=, which uses the seed oil content to calculate the moisture level at a certain RH. The oil content in the database behind the web site is based on a literature search and may contain different figures for the same crop. The latter is logic as the seed oil content is influenced both by seed production conditions and genetic variation. Using this web based tool, it can be calculated that a considerable part of the storage potential of seeds may be lost between harvest and warehouse storage, related to high moisture and temperatures.