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SEED DRYING FOR GERMPLASM CONSERVATION

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Orthodox seeds can be dried to low moisture contents with considerable advantage to longevity. Seed drying involves the evaporation of moisture from seed surface into the outer atmosphere and is influenced primarily, by the gradient in relative humidity between the seed and drying environment. The various methods of drying seeds to reduce moisture content for subsequent storage were discussed. Sun-drying, although is the cheapest method usually practiced, affects seed quality and is impractical in humid tropics due to the prevailing high relative humidity. While using commercial seed dryers for artificial drying, proper control of the air temperature is essential to minimize seed deterioration. A low temperature-relative humidity drying is recommended to reduce the moisture content to 5±2 per cent for long-term conservation of the germplasm seeds. The relative advantages and the associated problems in drying seeds to such low moisture content are discussed.

Seeds of many diverse species can be dried to very low moisture contents with considerable advantage to subsequent longevity during storage (Roberts, 1979). It has been shown that, over a wide range of moisture contents, there is a negative logarithmic relationship between seed longevity and moistue content (Ellis, 1991). Moisture control, primarily by drying also provides an opportunity to prevent losses which occur during harvesting and subsequent handling, estimated to be about 10 per cent of the grain produced (Hall, 1980). Consequently, seed drying methods, have been the most important aspect of processing to prepare seeds for storage. However, seed drying needs considerable care because inappropriate methods can lead to unnecessary seed deterioration. Hence, it has been a subject of intensive investigations,

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especially in climates where the ambient relative humidity is high. In this paper, the principles and practices of seed drying are discussed with special reference to seed conservation in genebanks.

FACTORS AFFECTING SEED DRYING

Equilibrium moisture content

Seed drying involves the evaporation of moisture from the seeds into the outer atmosphere and is directly related to the equilibrium moisture content of the seeds. Under all storage conditions, the moisture content of the seeds comes to an equilibrium with the relative humidity of the surrounding atmosphere. For a given species, there is a definable equilibrium relationship between relative humidity and seed moisture content, although the biochemical composition of the seeds which can in turn be affected by the genotype and the growing environment has a slight effect on this relationship (Justice and Bass, 1978; Cromarty *et al.*, 1982).

The equilibrium relationship between seed moisture content and relative humidity at a constant temperature of 25°C in the mandate crops of ICRISAT is presented in Fig. 1. These data were obtained by allowing the seeds to equilibrate in environments with known relative humidity, obtained by saturated solutions of KOH or aqueous solutions of H_2SO_4. The equilibrium curves (or sorption isotherms) have a characteristically sigmoid shape with three distinct phases which correspond to the three different states of seed hydration (Vertucci and Leopold, 1987). At the driest end, the curve represents the water that is tightly bound to the macromolecules and this kind of water cannot be easily removed without destruction of the seed tissues. The next phase of the curve is represented by water that is loosely bound which can be removed by forced drying. The upper part of the curve represents water that is loosely held by weak bonding and free water in the intercellular spaces, which can be easily removed by simple drying. The moisture equilibrium curves are only slightly influenced by temperature, moisture contents being a little lower in warmer temperatures than in cooler, and vice versa

Temperature, air flow rate and vapour pressure

The rate of loss in seed moisture is influenced positively by temperature, air flow rate and the difference between initial seed moisture content and the equilibrium seed moisture content at the relative humidity of the drying environment (Cromarty, 1984). Since the rate of seed deterioration is influenced positively by temperature, the choice of suitable temperature for seed drying compromises the positive effects of temperature on both the rate of drying seeds and seed deterioration.

the general advise: if the initial moisture content is between 18 and 30 per cent, the air temperature should not exceed 32°C, if it is between 10 and 18 per cent, then air temperature of 40°C can be used. However, commercial recommendations, determined empirically in temperate countries to minimize damage during drying are unsuitable for poor quality seeds, heterogeneus seed lots and where the final moisture content aimed is as low as 5 per cent. Heated air drying was shown to induce dormancy in sorghum (Nutile and Woodstock, 1967). When the grain is over heated during artificial drying, the quality also may be affected in a number of ways. For example, if the temperature is high and relative humidity of air low, moisture will be removed rapidly than water can diffuse from the inner layers of the seeds and a hardening or casing may be formed. The impervious layer will prevent free diffusion of moisture and will cause grain to become wrinkled, scorched and discoloured. Rapid drying can cause internal cracking as in rice, soybean and maize with serious implications for conservation (Boxall and Calverley, 1985). On the other hand, in humid tropics the reduction in relative humidity resulting from heating the air would not be sufficient to dry the seeds to low moisture contents needed especially for long-term conservation.

Low temperature drying

An alternative method which uses lower temperature (about 15°C) and an atmosphere with low relative humidty (10-15%) is recommended for drying seeds, especially for long-term conservation, where recommended seed moisture content is 5±2 per cent (IBPGR, 1976). This requires the use of an air-dehumidifier with refrigeration to lower the temperature and remove the heat generated by dehumidifier. A seed drying cabinet manufactured to this design by Munters Ltd. (UK)* is being used effectively to dry the seeds of sorghum, pearl millet, chickpea, pigeonpea and groundnut for long-term conservation at ICRISAT. Larger seeds however, require substantial time to dry, hence a two stage drying procedure was suggested. In the first stage, drying could be carried out at 17°C with 40-45 per cent RH and in the second stage, seeds are placed in a dryer with good air circulation at about 30°C and 10-15% per cent RH (Cromarty *et al.*, 1982).

ADVANTAGE TO DRYING TO ULTRA-LOW MOISTURE CONTENTS

The advantage of dehydrating seeds to very low moisture contents is well known for several crops which produce orthodox seeds. For example, drying cereal seeds from 9 to 8 per cent moisture content

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doubles their storage life. Further decreases are shown to be even more beneficial, as drying from 5 to 4 per cent increases longevity by a factor of 3.7 (Roberts, 1989). Although little further desiccation of starchy seeds, the moisture content of many oily seeds could be further reduced to values between about 2 and 4 per cent with considerable benefit. For example, decreasing seed moisture content from 5 to 3.5 per cent in onion, and 2 per cent in groundnut increases longevity by a factor of 8 and 42, respectively (Ellis *et al.*, 1990b). Similarly, storage of *Brassica napus* seeds with 3.5 per cent moisture content instead of 5 per cent increases the half-viability period by 12 times (Ellis *et al.*, 1989). In view of the above, preservation of ultra-dry seeds is suggested to be a promising technique which might enable the cost of refrigeration reduced or even avoided. In this context, it is important to know whether extreme desiccation causes losses in quality of seeds or in viability and vigor.

PROBLEMS IN DRYING SEEDS TO LOW MOISTURE CONTENTS

Imbibition injury

Although there are essentially no reports on seed damage caused by drying to approximately 6 per cent moisture content, several workers have reported damage when seeds were dried to 5 per cent or lower (Toole and Toole, 1946: Roberts, 1959). Nutile (1964) found that sorghum seeds dried to 3 per cent moisture content showed more delayed germination and produced abnormal seedlings with damaged radicles, but the apparent injury was overcome by placing the seeds at 55 per cent relative humidity which increased the moisture content to 11 per cent. McCollum (1953) and Pollock and Manalo (1970) attributed the cotyledon cracking in garden pea to rapid imbibition of water during germination, since cracking was less when the seeds were humidified to about 12 per cent imbibition. Indeed much of the damage considered as desiccation damage was shown due to the stress caused by rapid uptake of water when dry seeds are placed in direct contact with water for germination (Ellis and Roberts, 1982; Ellis *et al.*, 1990a). Therefore, seeds can be dried to low moisture contents to prolong viability, but sensitive seeds require special handling before planting. Seeds must be allowed to equilibrate with normal atmospheric conditions, but in very dry arid areas, special humidification will have to be employed.

Hardseededness

In many species, the seed coat becomes impermeable to moisture ingress when dried to low moisture contents. This results in hardseededness which is particularly prevalent in the family

Leguminoseae, but may also be seen in other families, for example, Malvaceae, Rosaceae, Convolvulaceae etc. When 100 pigeonpea accessions were screened, the percentage of hard seeds varied from zero to 71 per cent (Remanandan *et al.*, 1991). Two levels of hardseededness are recognized: as the seeds are dried to about 10-12 per cent moisture content, they become reversibly hardseeded, which soften when exposed to high relative humidity for a long time. When seeds are further dried to about 5 to 7 per cent moisture content, they tend to become irreversibly hardseeded, which are likely to be a problem for genebanks, especially in wild species of cultivated crops which have thicker seed coats (Ellis *et al.*, 1985). Unless specially treated, irreversible hardseededness by affecting plant stand when sown for regeneration, results in genetic shifts by selection of non-dormant types in heterogeneous germplasm accessions. However, hardseededness can be easily removed either by mechanical or acid scarification.

Cleavage damage

Considerable difficulty is encountered in soybeans and some genotypes of chickpea while the seeds are dried to low moisture contents. If rapidly dried, the seed coats crack and the cotyledons separate-manifesting in what is known as cleavage damage (Rao *et al.*, 1990). To avoid this type of damage, soybean seeds are recommended to be dried in an environment with relative humidity of not less than 40 per cent (Cromarty *et al.*, 1982). In chickpea, the seeds have to be dried slowly, initially at about 40 per cent RH to an equilibrium moisture content of 8-9 per cent and then at 10-15 per cent RH for further reduction in moisture content (Rao *et al.*, 1990).

CONCLUSIONS

Seed drying, by removal of excess moisture in seeds reduces grain respiration and thereby slows deterioration. The growh of microorgaisms and insects is also inhibited by drying. In many crops for general storage, the appropriate moisture levels recommended vary between 10 and 12 per cent, depending on crop. Organizations involved in seed production can plan their seed multiplication activity in areas where the crops attain harvest maturity when the ambient atmosphere is cool and dry. This enables production of good quality seeds with moisture content sufficient enough for direct short term storage, without recourse to postharvest drying. However, in humid tropics and in temperate climates, seed drying is imperative, and unless operated with care, it may adversely affect seed quality. Whatever method is used for drying, there is likely to be some effect on overall seed quality, since the same factors: temperature and time, which affect seed drying also contribute to seed deterioration. It is important that the choice of suitable drying system should involve minimum seed deterioration during drying. Unfortunately, sun-drying and hot air drying, are by far the most common methods of drying seeds after harvest, although it is possible to reduce seed moisture content by other safer means. For example, substantial amounts of water can be removed without adversely affecting seed quality, by forced movement of dehumidified ambient air. Where ambient relative humidity is very low, drying rate can be maximised by increasing air flow rate in a thin layer drying without the need to heat the air. The IBPGR recommended conditions for drying (15°C and 10-15% RH) ensure minimum damage to the seeds, especially important while preparing seeds for long-term conservation in genebanks.

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