Simple and Effective Drying and Storage of Seeds and Horticultural Products for Developing World Farmers

Delivering improved seeds to smallholder farmers in the developing world is an efficient and sustainable method of increasing crop yields and quality. Unlike fertilizers, pesticides and equipment, seeds can be produced locally for distribution to farmers or self-saved. Furthermore, improved varieties of horticultural crops often reduce dependence on synthetic pesticides, improve food safety, reduce pre- and post-harvest losses and fetch higher prices in the market. However, the benefits that developing world farmers accrue from improved varieties can depend on their local systems for seed drying and storage. Without proper storage conditions, seeds can rapidly lose viability, resulting in poor crop establishment, lack of uniformity, reduced yields and poor marketability. Farmers' experience with poor seed performance lowers their incentive to invest in genetically improved seeds and stymies development of breeding and seed marketing systems for more productive horticultural varieties. On the other hand, farmer confidence in the quality of purchased seeds and in their ability to store them safely will strengthen local seed markets and increase yields and incomes.

Seed storage can be a major problem because the majority of the world's poor countries are located in the tropics, where the combination of high temperature and high relative humidity causes rapid deterioration of seed quality. In South Asia, seeds harvested before or during the monsoon season need to be dried and stored until the next planting season. The relative humidity of the air for most of the period between harvest and planting often exceeds 75% and temperatures remain above 30°C, causing seeds to deteriorate rapidly. Seeds absorb water from the ambient air when they are stored in humid environments and lose water when stored in low relative humidity. Generally speaking, a seed's longevity is reduced by approximately half for every 1% increase in seed moisture content (water content as a percent of fresh weight) or 5°C increase in temperature, and the effects are additive. Thus, seeds stored at 10% moisture content and 30°C will last only one-quarter as long as seeds stored at 9% moisture content and 25°C. This principle implies that seed storage life can be enhanced considerably by lowering both moisture and temperature. However, moisture content is the key factor that can be lowered for successful seed storage in tropical countries. Cold storage is expensive and difficult to maintain because electricity supplies are often inconsistent and unreliable. In addition, seeds that are dried to low moisture contents are more tolerant of storage at warm temperatures. However, even prolonged sun drying in high humidities cannot reduce seed moisture content to the levels low enough to assure long-term viability.

These problems can be overcome by drying seeds to low moisture contents using inexpensive hermetic containers and zeolite drying beads, a recently developed desiccant technology. Using drying beads, seeds can be quickly and efficiently dried to safe storage moisture contents, and storing seeds in hermetic containers not only maintains low moisture contents, it also prevents losses to rodents, insects and molds. Seed desiccant drying beads provide a simple, inexpensive and reusable method for seed drying in humid climates. In addition, the beads can also be used to dry herbs, vegetables, fruit, nuts, medicinal plants, or other horticultural products.

What are seed drying beads?

Seed drying beads are modified ceramic materials (aluminum silicates or "zeolites") that specifically absorb and hold water molecules very tightly in their microscopic pores. The beads will continue to absorb water until all of their pores are filled, up to 20 to 25% of their initial weight. When placed in an enclosed space like a plastic or metal container, the beads will remove water from the air, creating and maintaining a very low humidity environment. Seeds (or other materials such as fruits or herbs) placed into a container with the beads will lose water due to the low air humidity, and will continue to do so until they come to equilibrium. Hence, desiccant-based drying simply transfers the water in the seed to the drying beads through the air without the need for heating. The beads can subsequently be removed and regenerated separately by heating at >200°C for 2 hours to release the absorbed water.

Traditional seed drying methods

Traditional seed drying methods practiced by farmers for ages have relied on ambient conditions or sun drying. Seeds are often dried partially in the field by cutting and windrowing plants before harvesting and either storing intact, as corn on the cobs, for example, or threshing the seeds before storage. For wet fleshy fruits like tomatoes or melons, the seeds are extracted and washed before drying. Seeds are then generally spread in the sun during the day and may be collected and covered during the night to prevent rehydration from dew. This procedure often needs to be repeated daily until the seed moisture content is reduced sufficiently for storage. While this system works well in sunny and dry climates, it cannot reduce seed moisture content to safe storage levels when the ambient humidity is high. At best, the seeds can only dry to the level in equilibrium with the ambient humidity.

Advantages of bead drying

A major advantage of bead drying is that it is not dependent upon the sun or other direct sources of energy and it is independent of the ambient humidity. It does require the use of moisture-proof containers in which the beads and seeds can be enclosed. Once both the beads and seeds are in the closed container, the transfer of water from the seeds to the beads will occur automatically. In addition, by enclosing the seeds in a container, they are protected from rodents, birds, insects, molds and rainfall. The time needed to spread and collect the seeds daily and protect them from birds and rainfall during open drying will be saved. Once the seeds have reached the desired moisture content, the beads can be removed and the seeds will stay at that moisture content as long as they remain within the moisture-proof container. Seeds dried to these to low moisture levels can be stored for several years even at warm temperatures. It is more convenient to use this method with vegetable and other high-value, low-volume seeds than with the large quantities of seeds utilized in agronomic crops such as cereals or legumes. Nonetheless, there are ways to utilize drying beads on larger industrial scales and store the seeds in hermetic packaging.

Enclosing seeds inside of sealed containers goes against most traditional knowledge about seed storage. Enclosing moist seeds in such containers will result in damage due to molds and insects. Thus, traditional knowledge is correct in humid regions where it is not possible to dry the seeds to the low levels required for safe storage in sealed containers. However, the addition

of drying beads to the seeds in the sealed containers, by lowering the seed moisture content, changes everything and results in the multiple advantages of greater seed longevity as well as protection from losses due to animals, insects and molds.

Why not just use silica gel or other desiccants?

Seed drying with desiccants is not a novel technology, and specific drying equipment based upon silica gel is available. Even other seeds, such as rice grains, when heated to dry them to very low levels, will absorb moisture from other seeds and act as a desiccant. However, silica gel has less affinity for water than seed drying beads at the low humidities needed to dry seeds to optimal storage moisture contents. Also, while silica gel can be regenerated by heating at relatively low temperature, there is loss of water-holding capacity with each cycle and it must eventually be replaced. In contrast, there is no loss of water-holding capacity of seed drying beads when heated for regeneration. It has been estimated that they could be regenerated a minimum of 10,000 times without loss of capacity. The beads are non-toxic and pesticide-free.

Equipment needed

Any type of locally available airtight container (plastic, metal can, etc.) of any size can be used. A gasket inside the cap may be needed to ensure airtight conditions in plastic or metallic containers. A simple test can determine whether the container is airtight. Place a small quantity of fresh indicator silica gel inside the container for a few days. A color change indicates that the container is not moisture proof.

An oven or other heat source is needed to regenerate the beads for reuse. This can be any type of oven capable of heating to over 200°C (~400°F). For example, an oven for baking bread could be used to regenerate the beads. After heating for 2 to 3 hours, the beads should be cooled in a metal container with a lid (to reduce re-absorption of water) until they can be safely handled, then stored in a moisture-proof container.

Beads can be mixed with the seeds for more rapid drying, and can be easily screened out from the seeds for reuse (beads can be produced in different sizes to be easily separated from various types of seeds). Alternatively, the beads can be enclosed in a porous bag or container within the hermetic container for convenience. The only requirement is that beads and seeds be in contact with the same atmosphere that is sealed from the external atmosphere. Wet seeds, such as fresh tomato or melon seeds, should be surface dried by the sun or other method before mixing directly with seed drying beads. **Note: adding liquid water directly to dry beads generates heat. Avoid bringing liquid water into direct contact with dry beads.**

Can drying beads damage seeds?

If an excess of beads is stored with seeds, the seed moisture content will be reduced to very low levels. Most desiccation-tolerant (“orthodox”) seeds are not damaged even when dried to 3-5% moisture. Some larger seeds, particularly cucumber, watermelon, bottle gourd and bean, can be damaged by rapid rehydration from very low moisture contents, called imbibitional damage. To be safe, it is a good practice to remove seeds from the sealed storage container and allow them to rehydrate in air under ambient conditions for a few days prior to planting or

bringing into contact with liquid water. In most tropical regions, the ambient humidity will safely rehydrate the seed sufficiently to prevent imbibitional damage. Some seeds also become brittle when very dry and should be handled gently until they have had a chance to rehydrate from the humid air. This is particularly important for bigger seeds like beans.

Some seeds (termed "recalcitrant") are damaged by drying and should not be dried using desiccant beads. Many tropical tree seeds like mango, durian, and palm or other seeds like citrus are recalcitrant and should not be dried using these beads.

Precautions

The beads release heat by an exothermic reaction when they absorb water. At the rate that water is absorbed from the air, this heat is readily dissipated and no discernible increase in temperature will be detected. However, if liquid water is added directly to dry beads, the rapid release of heat will raise the bead temperature to levels that can be injurious to the seeds and to workers. Thus, **Do Not** add beads directly to very wet seeds such as cucumber, melons or tomato seeds immediately after washing. Dry the seeds in air first to remove excess water before mixing directly with beads.

Other uses for drying beads

The drying beads can be used to dry fruits, vegetables, nuts, herbs, or medicinal plants, to purify essential oils, or other applications where the specific removal of water is desired. In many of these applications, drying is usually accomplished using heated air, which can remove flavor volatiles or reduce nutritional content, lowering the quality of the final product. As for seeds, simply enclosing the desired material inside of a hermetic container with the beads will effect drying to the desired final moisture content.

What quantity of beads is needed to dry seeds?

The amount of beads required depends upon several factors: 1) the water-holding capacity of the beads; 2) the quantity of seeds to be dried; 3) the initial seed moisture content; and 4) the final desired seed moisture content. Charts and tables (see below) make it easy to determine the ratio of seeds to beads needed. The water-holding capacity of the beads can vary somewhat depending upon how they have been stored and handled prior to use. To determine their current water-absorbing capacity, a small quantity of beads can be weighed and then placed inside of a container with an open container of water, a wet sponge, or other water source. After leaving sealed for a day, the beads can be removed and weighed again. The final weight minus the initial weight is the weight of water absorbed, and dividing this value by the initial weight gives the water-holding capacity.

$$\text{Bead water-holding capacity (\%)} = \frac{\text{initial bead weight} - \text{final bead weight}}{\text{Initial bead weight}} \times 100$$

For a given bead water-holding capacity (generally 18 to 24%), the charts below show the ratios of bead to seed weights that will reduce the indicated initial seed moisture content down to the corresponding final moisture content (Fig. 1). For example, for seeds at 25% initial moisture

content, if the beads will hold 20% of their weight in water, a 1:1 ratio of seeds to beads would reduce the final seed moisture content to 6% (Fig. 1). Kew Gardens provides a utility for estimating the initial seed moisture content for many species based on the ambient temperature and relative humidity (http://data.kew.org/sid/viability/mc1.jsp). The same charts would work for any other materials when moisture content is expressed as a percentage of fresh weight.

Cost

The only costs are a one-time initial investment to purchase the drying beads and containers and the energy required for regenerating the beads for re-use. The cost of the beads is dependent upon location due to variation in import duties, taxes, etc., but is expected to be on the order of US$10 to US$20 per kilogram. Since the beads can be reused indefinitely, the initial investment would be spread over many years of potential use. This investment should be considered in relation to the value added by improved seed quality, the avoidance of economic losses due to seed deterioration, the time and labor saved relative to sun drying and the losses avoided that would normally take place due to rainfall, birds, insects, rodents, and fungi in ambient air drying and storage.

Where can I get seed drying beads?

Rhino Research Group distributes seed drying beads. The availability of beads currently varies by country depending upon local dealers. For further information, contact Rhino Research, Moo Baan Sai Samphan 66/17, 66000 Phichit, Thailand, +66 56 650 646, www.rhino-research.com, rrc@rhino-research.com.

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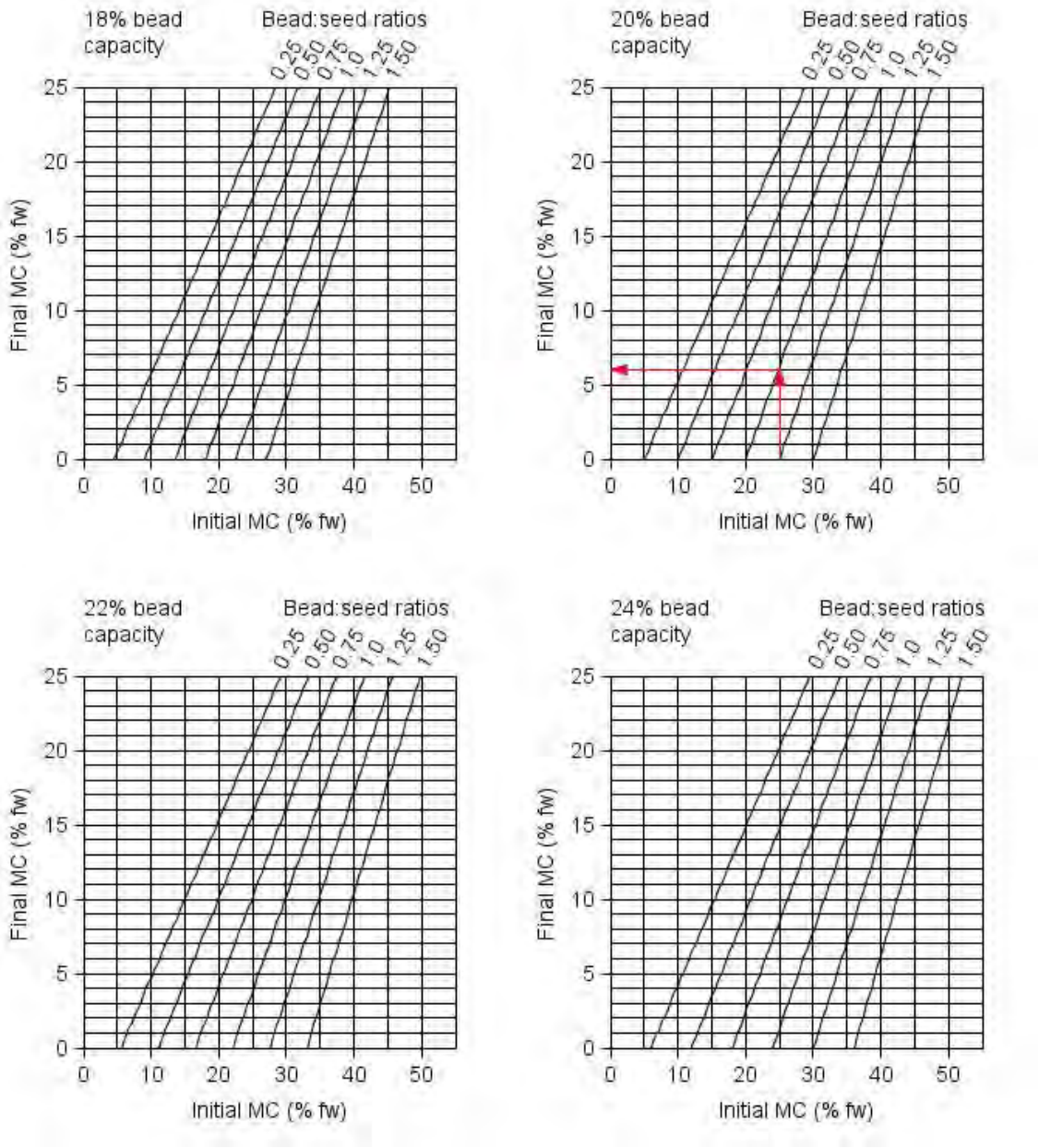

Figure 1. Charts to estimate the bead:seed ratio required to reduce initial seed moisture content to different final moisture contents. Lines show the relationships between the initial (x-axis) and final (y-axis) seed moisture contents for different bead:seed weight ratios. The different graphs show the relationships for 18, 20, 22 and 24% bead water-holding capacities. Arrows show the example described in the text. Although the lines show seed moisture content going to zero, in practice the minimum final moisture content is generally not less than 2%.