Vacuum Sealing vs. Refrigeration: Which is the most effective way to store seeds?

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Introduction

Storing seeds in the tropics can often be difficult; with high temperatures and humid conditions, seeds lose their ability to germinate quickly. Many techniques for seed storage exist, from the high-tech standards of gene banks to simple methods used by villagers for saving their own seeds. All have their strengths and weaknesses, but when balancing costs and resources, which methods are really the most effective? To find appropriate low-input storage methods for storing seeds, the ECHO Asia Seed Bank recently completed a study on tropical seed storage under the resource-constrained settings this seed bank encounters.

The three key factors that determine the rate of seed deterioration in storage are: oxygen pressure (amount of oxygen with the seeds in storage), seed moisture content, and temperature (Roberts, 1973). An increase in any of these factors will lower the storage life of the seeds, and as a general rule any increase of 1% moisture content or 10^{o} F (5.6^{o} C) in storage will halve the storage life of the seeds (Bewley and Black, 1985). Each factor contributes to seed decay in specific ways, and minimizing these conditions is critical to effective seed storage.

The goal of this research was to evaluate two seed storage options: vacuum sealing and refrigeration. Vacuum sealing is a relatively low-cost method that requires few inputs after an initial investment. Sealing helps conserve seed quality by minimizing oxygen presence and exposure to ambient humidity, thereby keeping seed moisture content low. Refrigeration minimizes temperature, but can also be expensive to maintain in tropical conditions. We used five tropical seed varieties to compare the effects of these storage methods over the course of one year; our goal was to use the outcomes of this study to help prescribe storage conditions for this seed bank and others like it around the world.

Experimental Design

We compared five different crop species grown in the tropics: tomato (*Solanum lycopersicum* 'Juliet 1437'), pumpkin (*Cucurbita moschata* 'Nang kaang kot'), moringa (*Moringa oleifera* 'Local Mix'), lablab bean (*Lablab purpureus* 'Chiang Dao'), and amaranth (*Amaranthus cruentus*, 'USDA PI 606767'). Each species was chosen to represent a different kind of crop, but each species also fills a different role in the agricultural development work of the ECHO Asia Seed Bank. Tomatoes are used as income-generating cash crops and have been promoted by the Thai government as an alternative to the opium poppy (Anderson, 1993). Pumpkin is a cucurbit, a staple among local people, but especially important to poorer families for nutrition (Anderson, 1993). The moringa tree is growing in recognition due to the exceptional nutritional content of its leaves (Oduro *et al.*, 2008), and lablab bean is used as a green manure/cover crop while the seeds themselves also provide protein, vitamins and minerals (Kabir Alam *et al.*, 2008). Grain amaranth has great potential for increasing food security because of its drought-, heat-, and pest-resistant qualities (Ronoh *et al.*, 2009).

Seeds were stored in one of four treatments: paper packets/non-refrigerated, paper packets/refrigerated, vacuum sealed/non-refrigerated, vacuum sealed/refrigerated (Table 1). Seeds were sealed together based on species and storage treatment, then tested after 0, 3, 6, 9, and 12 months of storage; all seeds were evaluated for germination rate, mean time to 50% germination, seed moisture content, and field emergence. Both germination rate and mean time to 50% germination were calculated from petri dish germination of 20 seeds in laboratory conditions, while field emergence measured germination in potting soil. Seed moisture content was determined by grinding seeds to a fine grit before drying for 15 hours at 100^{o} C. All tests had four replications, for a total of 400 packets of seeds.

Table 1. Experimental design showing different moisture and temperature regimes created by the four storage methods.

Storage Method	Vacuum sealed	Paper Packets
Refrigerated	Constant moisture Constant temperature	Fluctuating moisture Constant temperature
Non-refrigerated	Constant moisture Fluctuating temperature	Fluctuating moisture Fluctuating temperature

Results

Over 12 months of storage, many patterns emerged as the seeds slowly deteriorated. The method of seed storage had a highly significant effect on seed quality over this period ($p < 0.0001$), but the type of seed was an equally important factor. The combination of refrigeration and vacuum sealing was the best storage method for each of the aspects of seed quality we measured:

germination rate, mean time to 50% germination, moisture content, and field emergence. However, the relative importance of vacuum sealing and refrigeration was not the same for each of these measures.

Differences between storage methods were most evident in the germination rate data, as there was an almost 20% drop in germination rate between each storage treatment by the end of the experiment (Figure 1). Although refrigeration and vacuum sealing together was the most effective method for preserving germination capacity, overall, vacuum sealing alone was more effective than just refrigeration. Germination rates in the field largely mirrored these results, though with more variability due to the nature of the measure. These results show that vacuum sealing may be a more effective seed storage technique than refrigeration, especially for preserving the capacity of seeds to germinate in the lab and the field.

The outcomes for mean time to 50% germination were slightly different. As Figure 2 shows, refrigeration without sealing was slightly more effective than vacuum sealing without refrigeration at conserving a lower mean time to 50% germination (faster germination). These results suggest that storage methods affect various aspects of seed quality differently. While vacuum sealing was more effective than refrigeration at conserving seeds' capacity to germinate, it may be less useful for promoting the speed of germination. For the majority of seed quality measures, however, vacuum sealing proved to be the more effective way to conserve high seed viability.

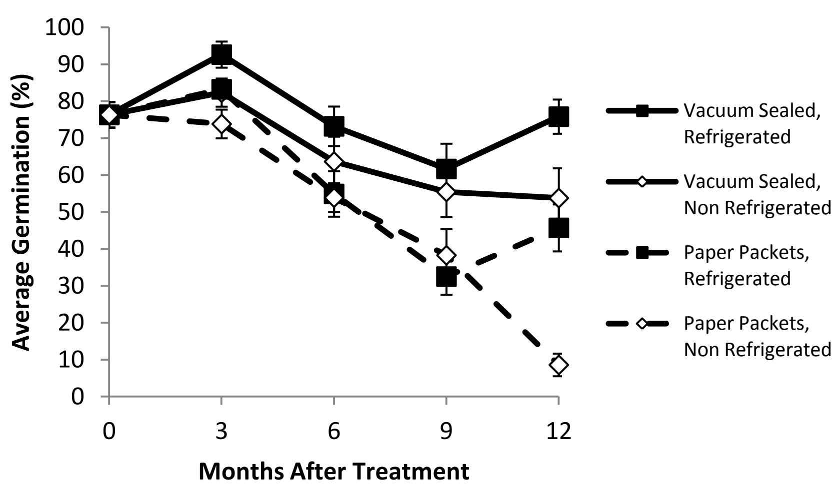

Figure 1. Average germination rate by storage treatment over the 12 months of storage. Error bars represent ± 1 SE of the mean.

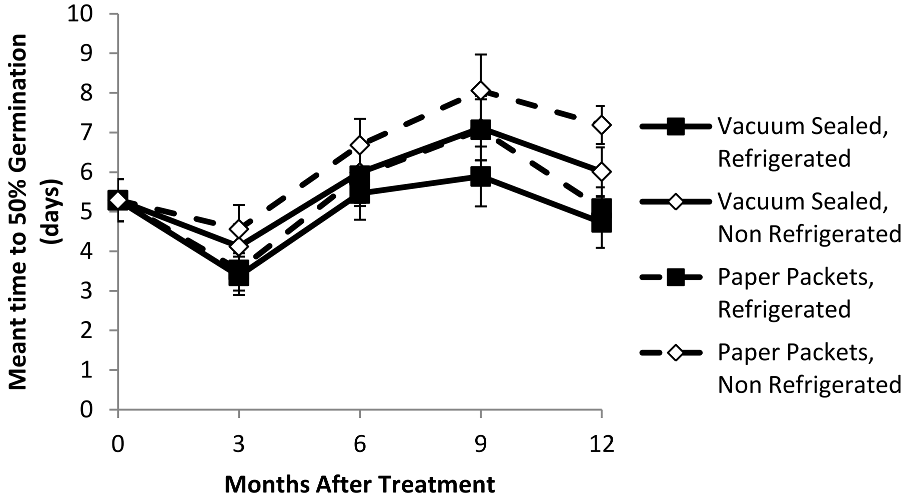

Figure 2. Mean time to 50% germination by storage treatment over the 12 months of storage. Error bars represent ± 1 SE of the mean.

While vacuum sealing never had any negative effects on seed moisture, refrigeration in combination with paper packets (fluctuating moisture) did dramatically increase seeds' moisture contents (Figure 3). The combination of high humidity in the refrigerator (sometimes as high as 98%) with paper packets that actively absorbed this moisture meant that the paper packets/refrigerated treatment had significantly higher seed moisture than any other treatment. This means that while refrigeration on its own may be a useful seed storage tool, storing seeds for long periods of time without a way to control moisture (e.g. vacuum sealing) is a poor choice for keeping seeds dry.

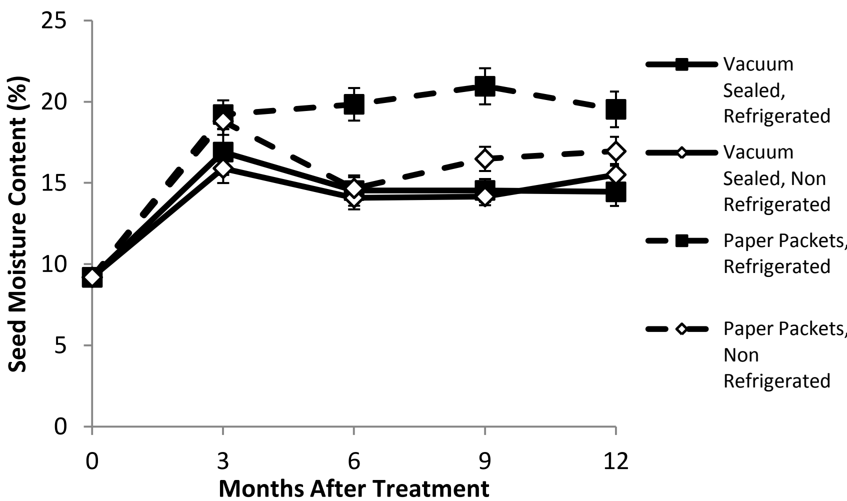

Figure 3. Mean seed moisture content by storage treatment over the 12 months of storage. Error bars represent ± 1 SE of the mean.

Differences in seed species were also critically important for determining rates of seed degradation. While some seeds were particularly prone to rapid degradation in storage, others maintained high seed quality even when stored at ambient conditions. Matching seeds to their individual requirements will most efficiently allocate resources, though this requires a thorough knowledge of each seed type.

Throughout the 12 months, lablab seeds maintained a higher germination rate than other seed types across all treatments (Figure 4), which may indicate that lablab bean, and perhaps legumes in general, do not require as many resources for storage. Both moringa and tomato, on the other hand, distinguished themselves as performing poorly in almost every measure. Pumpkin seeds generally fell in the middle range for most measures, and may be a good standard by which to gauge other seeds' quality in storage. The amaranth seeds were prone to erratic performance and though generally strong in mean time to 50% germination, amaranth had some of the lowest germination rates in the field. Ultimately, field performance is the most important test for seed quality, indicating that amaranth might be a seed species that requires more careful storage.

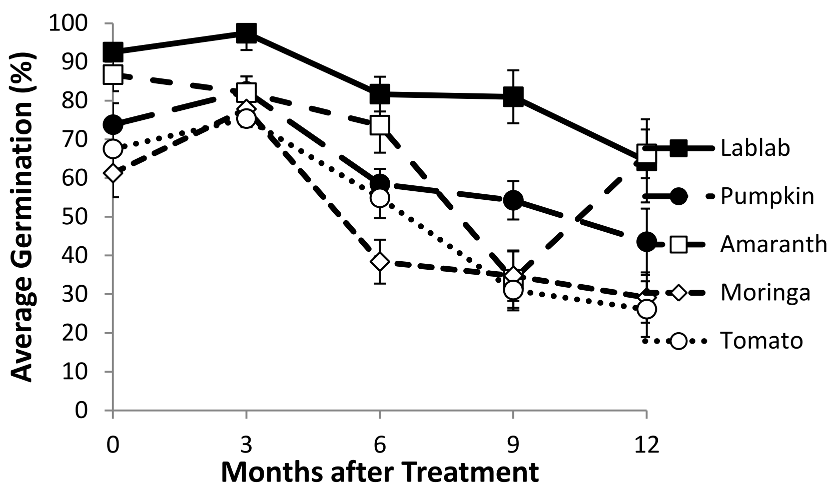

Figure 4. Average germination by seed species over the 12 month storage period. Error bars represent ± 1 SE of the mean.

Summary

While our results were not always consistent across all seed species and storage methods, several trends emerged that can be applied at seed banks and village level seed saving in the developing world. When available, the combination of vacuum sealing and refrigeration can contribute to preserving high seed quality in storage. If you had to choose one storage technique, vacuum sealing alone is generally more effective than refrigeration alone. Avoid storing seeds in permeable packaging (such as paper packets) in the refrigerator, which will decrease stored seed viability. For best results, vacuum sealing can be performed with commercial, residential sealers, and low-tech, low-cost methods like the bicycle pump-turned-vacuum sealer (see http://www.echonet.org/data/sites/2/Documents/OuagaForum2010/VacuumTirePump.pdf, pictured to the right).

Currently, ECHO Asia Seed Bank stores all seed species in vacuum sealed packages in an air-conditioned room. While the air conditioning does not keep seeds at refrigerated temperatures, it does help to minimize both temperature and humidity in the seed storage room. This slows the rate of deterioration and has proven to be an effective method for seed storage in these conditions. Appropriate village-level climate controlled structures (when used in conjunction with vacuum stored seeds) may include pits in the ground or earthbag structures (watch for this in future EANs). Our research has helped determine optimal storage methods for this seed bank, and we hope that it can be used to help others minimize costs while maximizing the storage life of their seeds.

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