SEED DRYING AND STORAGE IN HOT AND HUMID CLIMATES

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INTRODUCTION

This publication is for small-scale farmers interested in practical and effective seed drying and storage practices that prolong the shelf life and quality of seeds. Whether seeds are purchased or saved, it is worthwhile to protect them to prevent spoilage. The subtropical climate in North Florida is humid for the majority of the year, with exceedingly high temperatures from spring through fall, preventing optimal storage in ambient conditions. **An environment that is dry, dark, stable, and cool is ideal; if kept in these conditions, many crop seeds can last for several years.** Ultimately, the best practice to preserve seeds is to regularly plant and share them, but there will always be times when farmers, especially those saving their own seeds or storing bulk amounts of purchased seeds, will need storage options. This publication provides inexpensive and tested solutions for farmers to store their seeds.

Optimal conditions may not be achievable for some farmers, and may not even be necessary if seeds are being used within a short period of time. But any efforts made to improve storage conditions will help with seedling vigor, even if storage is only for a short period of time.

This publication covers three steps in the drying process from farm to storage:

1. Primary drying of unprocessed bulk seeds harvested from the farm.
2. Secondary drying after seed cleaning to prepare seeds for storage.
3. Optimal storage conditions for cleaned and/or purchased seeds (start here if only storing purchased seed).

CROP AND SEED TYPES INFLUENCE STORAGE TOLERANCE

Not all crops are equal in their tolerance to drying and storage. For example, some tropical fruits such as mango, avocado, and jackfruit, have recalcitrant seeds that cannot tolerate drying or storage and will die if not planted promptly. In their natural growing environment, it is more advantageous to grow immediately upon dropping to the ground, otherwise they risk being eaten or decaying quickly. Typical farm and garden varieties with orthodox seed types are generally more adapted to desiccation and storage; however, their longevity varies depending on factors like seed coat thickness and oil content. The information in this publication pertains to common vegetable, herb, and flower seeds grown on farms and in gardens that keep well in storage conditions.

OPTIMAL CONDITIONS FOR SEED STORAGE AND LONGEVITY

Seeds are living plants and should be treated thoughtfully to preserve not only their longevity, but their quality. Although in a semi-dormant state, they are responsive to environmental cues for growth including warmth, light, and moisture. These cues must be removed for seeds to remain in dormancy, by providing conditions that are **dry, dark, stable, and cool**. Of these, the most critical and hardest to achieve in warm and humid climates is dryness. Depending on the season, ambient conditions in North Florida can range from 50%-100% relative humidity throughout the year with an annual average of 89% in Gainesville, Florida (Florida Climate Center). Seeds eventually equilibrate with their environment, so the ambient relative humidity and temperature will determine the seed's conditions. Humidity should be removed as quickly as possible to prevent decay, insect outbreaks, and loss of seed vigor. **Ideally, seeds should be stored in conditions with relative humidity of 35% or less.** Low tech and inexpensive options can help achieve this, even in humid climates, and are described in this publication.

arugula seeds in dried pods

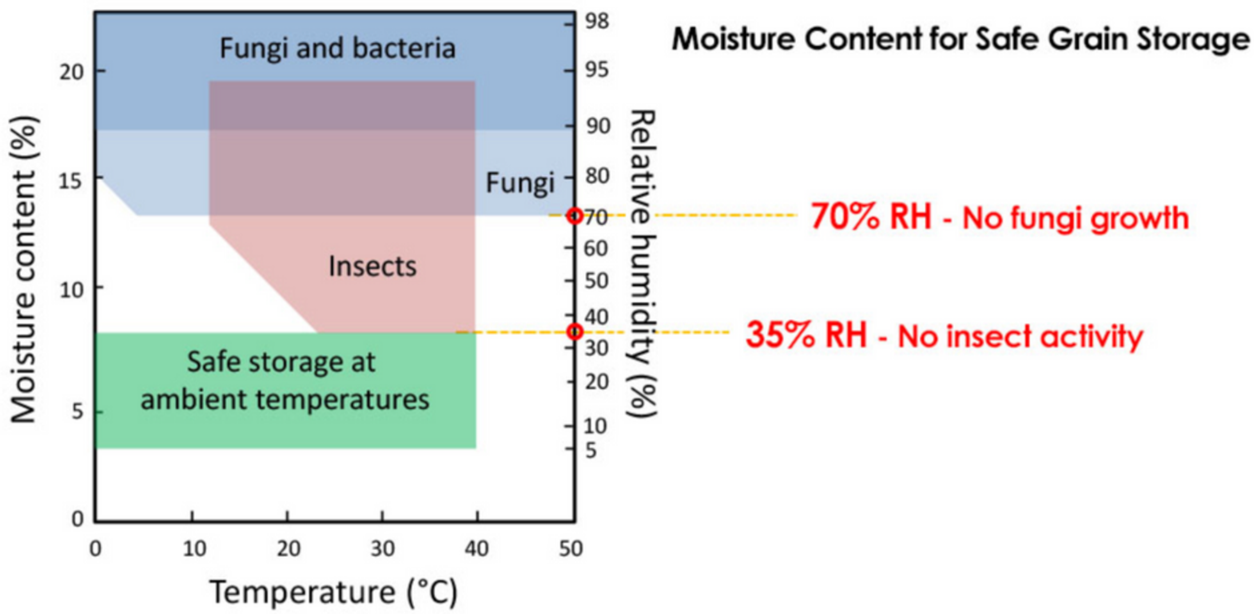

Figure 1: Temperature and moisture content of seeds effects on storage conditions. Source: Dry Chain.

High humidity is the #1 killer of seed longevity. A seed's longevity is reduced by approximately half for every 1% increase in seed moisture content. Seed storage can be enhanced greatly by lowering the moisture content within the seed, and is especially important in subtropical and tropical climates that experience high humidity nearly year round. Seeds dried to low moisture content are more tolerant of warmer storage conditions. **If seeds are adequately dried, they don't need to be chilled** (Harrington 1960). Reduced moisture content of seeds also reduces incidence of insect outbreaks that can devastate a seed lot.

It is often assumed that cold conditions are needed for seed storage. While this can be helpful in prolonging the life of a seed, it is not as important as moisture content, and should not be used if seeds are not fully dry. Home refrigerators and walk-in coolers are typically high in humidity, and therefore not ideal for storage. For example, a walk-in cooler for food storage typically maintains 95% relative humidity, while the freezer ranges between 80–90% relative humidity. With frequent use (people in and out, doors open and closed, defrost cycles etc.), the conditions change constantly, which is also detrimental to seed quality. **It is preferable to maintain stable conditions for fully dried seeds in an airtight container in ambient indoor room conditions.** A desk drawer, closet, or other space in the home or office will suffice. Refrigeration and freezing is not necessary.

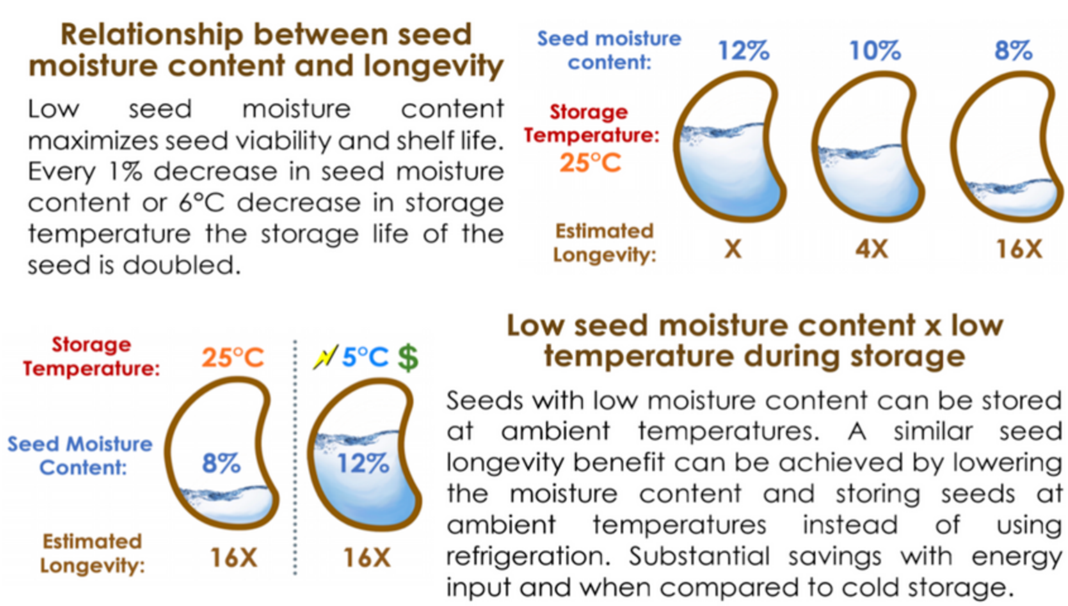

Figure 2: Low seed moisture content is not only more affordable and energy efficient than cold storage, but more effective in terms of seed longevity. Source: Dry Chain.

STEP 1: DRYING UNPROCESSED BULK SEEDS HARVESTED FROM THE FARM

Farmers saving their own seeds will need to process and dry them as quickly as possible. Harvest timing is critical, particularly in humid and rainy climates where one bad weather event can spoil an entire season of seed growth for some crops. This publication covers two types of crops: wet-seeded and dry-seeded. Crops in the wet category contain seeds inside fleshy fruit that need to be extracted, washed, and dried in a timely manner. Crops in the dry seeded category contain dry seeds inside pods, or fully exposed seeds that include many flowers and herbs. Each crop type has an optimal harvest time and special techniques for extraction, threshing, and winnowing. In hot and humid climates, seeds should not be dried in the sun when temperatures exceed 95F (McCormack 2004). Instead, the preferred situation is a climate controlled space or one with fans and good air circulation. Seeds should be processed, cleaned, and dried as quickly as possible to reduce incidence of moisture, mold, insect growth, and other undesirable impacts on seed quality. Additional details can be found in other publications and through hands-on experience with the crop, which provides the most valuable insights.

WET SEEDED CROPS

This group of seeds include crops such as tomatoes, peppers, winter squash, summer squash, cucumbers, watermelon, eggplant, and others that have seeds contained inside fleshy fruit. Once seeds are extracted from the fruit, they are rinsed and washed as best as possible to separate them from the surrounding material. Lay them out in a single layer on fabric napkins or towels, fine mesh screen, paper plates, or coffee filters. Regular paper, newsprint, and paper towels stick to seeds and are not advised. Every day, mix the seeds around to pull them off the material as they are drying to prevent sticking. Tomatoes can be gently rubbed between the fingers or palms to separate the seeds. More information about tomatoes, peppers, and winter squash can be found in our publications listed in the references section.

DRY SEEDED CROPS

This group of seeds include crops such as legumes (peas, beans, cowpeas etc.), brassicas (kale, collards, mustards, Asian greens etc.), okra, lettuce, and most flowers and herbs. They are more vulnerable to environmental humidity, thus farmers must be proactive at harvest time to stay ahead of inclement weather, and to prevent loss of seeds that may readily shatter, scatter, or blow away. Seeds contained in pods are much easier to shell if they are fully dried. If ambient harvest conditions are not conducive to drying, they should be brought indoors to fully dry. Once seeds are removed from their pods, simple winnowing with fans or wind, and sifting with screens can be used to separate more chaff from the seeds. It is important to remove pods and chaff as soon as possible as they may harbor insect eggs, pathogens, and moisture.

Figure 3: Left, a simple seed drying cabinet with box fans at Seed Savers Exchange in Decorah, Iowa. Seed varieties are held in mesh bags to keep them separated, and are individually labelled. Right, loosely filled crates of cowpeas sit in front of fans in a pole barn at The Family Garden in Gainesville, Florida.

Figure 4: Left, pepper seeds dry on a screen after most of the fruit is removed to eat, which allows better drying of the seeds. Right, a basic hardware cloth table can sun dry seeds on a warm day, and remove any morning moisture, but must be careful not to exceed 95F. Ambient humidity will prevent full drying but this can be a great first step to drying down bulk seeds. Photo taken at Florida Wildflower Cooperative in Alachua, Florida.

STEP 2: FINAL DRYING OF CLEANED AND PROCESSED SEEDS PRIOR TO STORAGE

Once seeds have been removed from their fruits and pods, and basic winnowing or cleaning is completed, they may still need additional drying before going into storage. The volume of seed, crop type, and resources available will determine the technique used. Below are some practical and accessible tools and supplies for low tech seed drying at a small to medium scale.

DRYING BEADS

Figure 5: desiccant beads and humidity tape.

Silica beads or ceramic zeolite beads (sold as Drying Beads®) are excellent for drawing moisture out of seeds, and can be reused many times. Silica beads are handy for their color changing properties which indicate when they are fully dry and able to draw out moisture or when they are saturated and no longer drawing moisture out of seeds. Drying Beads® do not change color as their saturation capacity changes, so knowing when to refresh them is more challenging compared to silica. Both types of beads work well to draw moisture out of seeds without creating heat. Drying Beads® however, have a higher affinity for water, especially at lower relative humidity levels. They are estimated to be available for regeneration a minimum of 10,000 times, whereas silica loses water holding capacity with each regeneration cycle. Either option will work for most small-scale growers and seed collectors. But when purchasing new supplies, Drying Beads® are recommended as they may be more effective and long lasting. Additionally, they are safe to use for food storage, so they can be used to lower moisture of dried fruits and herbs.

It's challenging to provide a general rule of thumb for a beads to seeds ratio, as seed oil content, temperature, and initial bead capacity all influence how much is needed. For practical purposes, the best approach is to **use roughly a 0.5: 1 to 1:1 ratio of beads to seeds**. Once beads are added, monitor the moisture content using estimates of relative humidity with an inexpensive hygrometer and/or humidity indicator tape. When sufficient moisture levels are obtained, remove the beads, and seal the container. If seeds need more drying but the relative humidity is not changing, replace with recharged beads until desired moisture is reached (Osmani 2023). The lower the relative humidity the better, but **general recommendations are to store crop seeds under 35%.**

Beads can be regenerated for re-use by drying them in an oven. **Drying Beads® are heated for 2.5 hours at 450-500F** with no more than two layers of beads on a flat tray, stirring throughout to redistribute beads. **Silica beads are heated at 175-250F for about an hour** or until stirred beads are evenly showing their starting color. Double check manufacturer's instructions for regeneration. While handling the hot beads is tricky, they should not be left exposed too long to cool down as they will start absorbing moisture right away, especially in humid conditions. Our technique is to carefully pour the hot beads into a large metal bowl, then carefully pour from the bowl into a glass jar with a canning funnel. Mason jars, or other glass containers that can handle high heat, work well. A fabric towel or cloth is then placed over top to absorb moisture, and the jar is sealed shut immediately. Another technique is to pour into a metal container that has a fitted lid and allow them to cool just until they can be handled and placed in a storage jar. More detailed information about Drying Beads®, including a calculator tool for estimating seed moisture content and bead amounts, can be found at dryingbeads.org.

DEHYDRATORS

Home scale food dehydrators can be used to dry larger seeds. As a general rule, **seeds should not be exposed to temperatures over 100 F to prevent damage** to the living embryo (Motis 2010). DIY larger size dehydrator cabinets that generate heat with incandescent light bulbs and airflow with fans can also be built. Details of these cabinets can be found in publications by ECHO listed in the references section.

DRYING RACK

Simple racks of screens can be repurposed from old windows, or custom built and fitted with box fans to keep air moving over the seeds as seen in Figure 6. Cabinets like the one in Figure 3, can be customized to insert fans. While these are great for drying down various types and volumes of seed, they will not fully dry seed in humid, unconditioned environments, like a barn. In these instances, piles of seed may need to be rotated frequently. In our experience using these in an unconditioned barn, it is sufficient to remove enough moisture to make the next step of seed processing more efficient, as some types of crops with seeds in pods can be very difficult to process when not fully dried (i.e. beans, peas, brassicas).

DRYING CLOSET

If a small closet or other enclosed space is available that has access to power, a temporary drying closet can be made. Ideally it is insulated with foam panels and has weather stripping around door cracks to prevent air leakage. Simple wire shelves can be inserted, and the closet fitted with a dehumidifier and circulating fan. The temperature increase of the dehumidifier will assist with drying, in addition to the dehumidified conditions. Inexpensive materials can be purchased at home improvement stores. Electricity costs are minimal and the supplies may only be a few hundred dollars. A similar setup is used for native plant nursery in Southwest Florida to dry sea oat seeds.

Figure 6: bulk seeds still attached to stems drying on screen racks with a box fan circulating air.

COMMUNITY SEED BANK HIGHLIGHT

The seed drying and storage room used by Working Food in Gainesville, Florida is modeled after the one built at The Florida Wildflower Cooperative in Alachua, Florida. It is designed to provide high quality storage conditions for medium to short term use (less than 10 years storage). A 10x10 walk in cooler with insulated panels is sealed to prevent temperature and moisture fluctuations. The space is kept fairly stable throughout the year at **72F** using a window air conditioning unit that vents to the outside. **Relative humidity is kept under 35%**, often dipping into the 20s during cooler and drier months. This is accomplished with a **dehumidifier that runs continuously** with a hose draining outside the barn under which it is housed. These two home appliances, purchased at local hardware stores, run continuously and are sufficient for the purposes of a community seed bank that keeps seeds in storage for 1-10 years. All cracks and holes are sealed, and lights are kept off except for when in use. While the energy cost will vary by utility, our unit uses an estimated 1,100 watts and **costs approximately $83/month to operate**. This option is best suited for farmers with large quantities of seed and available and dedicated storage space. This space can also be used to dry herbs, medicinal plants, and flowers. We have found excellent germination rates on seeds 7 years and older in conditions that, while not perfect, are both attainable and affordable. Most farmers are likely keeping seeds for a shorter period of time than this, unless storing bulk amounts of seed for long term use.

Figure 7: Inside, metal racks hold air-tight containers of seed that have been fully dried and cleaned.

Figure 8: The walk-in cooler is nestled into a corner of a tractor barn.

WHEN IS THE SEED DRY ENOUGH?

In large-scale seed systems, high tech seed moisture readers are used to measure the moisture content of seeds. Alternatively, moisture levels can be determined by comparing the fresh weight to the dried weight using specific calculations. These methods are not accessible to the typical small-scale farmer, and are not needed. Some crude but effective ways to test for seed moisture content are: 1) bite, smash, and snap tests; 2) using data in Figure 1 to estimate what the seed moisture content is based on crop type and relative humidity; and 3) estimating dry conditions based on a hygrometer reading or humidity indicator tape.

Figure 9: A hygrometer monitors ambient conditions next to drying pumpkin seeds. These numbers exceed the 100 rule and the relative humidity is too high. Seeds need more time to dry, and better drying conditions.

For large seeds, such as pumpkin seeds that can be held with fingers or small pliers, dryness can be tested by attempting to snap the seed in half. If they break cleanly, they are sufficiently dry. But if they bend or do not cleanly snap, they require further drying. Similarly, seeds like corn or beans can be tested by striking them with a hammer on a hard surface—if they shatter, they are dry, but if they flatten or smoosh, they still contain too much moisture and need additional drying. Another method is to lightly bite the seed; if bite marks are left, the seed is too moist and should be dried further until it resists indentation.

Charts of various seeds and their estimated seed moisture content based on ambient relative humidity are handy references, like one summarized in Table 1. Readings of ambient relative humidity inside seed storage containers can be obtained easily with an inexpensive hygrometer to estimate seed moisture content.

STORAGE CONTAINERS

Mason jars or other jars and containers with a tight fitting, rubber gasket type seal are inexpensive and effective at keeping moisture and air out. Packets or bags of seeds can be placed inside the containers, but storing seeds in open, breathable paper or mesh bags alone, is insufficient for good seed storage. Plastic bags are not sufficient as they have a porous nature and unreliable zipper closure, and cannot effectively keep air and moisture out. Filling up containers as full as possible is a good strategy to remove available oxygen from the seed, which reduces the incidence of insect pests like weevils (Dareus 2021).

Figure 10: Mason jars are excellent with screw top lids and rubber gasket seals. They should be kept in a dark location due to their ability to let light in. A vacuum sealing attachment can further remove air from the jars and create a tight seal.

VACUUM SEALING

For long term seed storage, vacuum sealing is an effective option. Humidity is kept out of the sealed container and oxygen levels are greatly reduced, which has been shown to extend the life of seeds and reduce the survival of insect pests like weevils (Motis 2019). Inexpensive home scale food vacuum sealers can be used to seal plastic bags, and simple attachments work to seal mason jars.

Important considerations for vacuum sealing are the volume of seed, sufficient low seed moisture content prior to sealing, and the frequency in which the sealed container will be opened. Large volumes of seed (how much will depend on the seed type and moisture content) should be split up and sealed in smaller quantities as too many seeds may generate too much heat or moisture as they respire. **Seeds should be dried as low as possible before sealing.** If the container of sealed seed is opened frequently, then vacuum sealing is not a good solution. Consider sealing only the seeds that won't be used for a longer period of time, whatever that means in your operation.

STEP 3: OPTIMAL STORAGE CONDITIONS

Once seeds are adequately cleaned, dried, and put into suitable containers, it's time to get them into the most optimal storage conditions available. **Seed storage conditions should ideally be dry, dark, stable, and cool.** If seeds are dried to the furthest extent possible and placed in an airtight container, any location in a climate controlled space that is out of the way and not frequently disturbed is sufficient (i.e. a dark closet, under a bed, or in a dresser drawer.) **Freezing will prolong the life of seeds even more, but must only be used if seeds are fully dried.** Seeds not fully dried risk being killed if ice crystals form and rupture cells. Further considerations are the frequency of use of the freezer. If it is opened regularly, this reduces the stable conditions as humidity, temperature, and light are changed each time the door opens. The same logic applies to home refrigerators that are frequently accessed, and may be very humid.

A rule used to generalize seed storage conditions known as "Harrington's Rule of 100", states that **the sum of relative humidity (%) + temperature (F) should not exceed 100** (Harrington 1960). Howeve,r since moisture is the most important factor, the rule stipulates that no more than half the sum should be contributed by the relative humidity. **Farmers should aim for a storage condition of less than 35% relative humidity inside sealed containers.** Once seeds are in these conditions, they will last for many years depending on the crop type.

SUMMARY

It takes some effort to dry harvested seeds and get them into good storage conditions, but the technology is minimal, affordable, and can be scaled to each system depending on the volume of seed being processed. For farmers saving their own seeds, this step is crucial to protect the investment of resources and time producing those seeds. Once dried and in sealed containers, seeds can be stored in warm or ambient conditions in a home or office setting, without the need for refrigeration or freezing. If cold conditions are available, the storage of fully dried seeds will prolong viability and quality.

Whipporwill cowpea seeds

Table 1: Moisture content approximations of some common crop seeds at 77°F (25°C). A reading of relative humidity (RH) is easily achieved with a hygrometer. Ideally, seed moisture content should be between 3-8% (IBPGR Handbook 1985). Seeds not listed may be estimated based on their closest related crop. Modified from Rao et al. (2006)

Crop	Relative Humidity (%)							
	10	15	20	30	45	60	75	90
Oily Seeds: Ideal 3-8% seed moisture content.								
Cabbage	2.9	-	4.6	5.4	6.4	7.6	9.6	-
Eggplant	3.1	-	4.9	6.3	8.0	9.8	11.9	-
Groundnut	3.0	-	3.9	4.2	5.6	-	9.8	13.0
Mustard	1.8	-	3.2	4.6	6.3	7.8	9.4	-
Okra	3.8	-	7.2	8.3	10.0	11.2	13.1	-
Radish	2.6	-	3.8	5.1	6.8	8.3	10.2	-
Soya bean	4.1	-	5.5	6.5	7.4	9.3	13.1	18.8
Turnip	2.6	-	4.0	5.1	6.3	7.4	9.0	-
Non- Oily Seeds: Ideal 7-11% seed moisture content.								
Bean, Lima	4.6	-	6.6	7.7	9.2	11.0	13.8	-
Beet	2.1	-	4.0	5.8	7.7	9.4	11.2	-
Buckwheat	-	6.7	-	9.1	10.8	12.7	15.0	19.1
Carrot	4.5	-	5.9	6.8	7.9	9.2	11.6	-
Cucumber	2.6	-	4.3	5.6	7.1	8.4	10.1	-
Lettuce	2.8	-	4.2	5.1	5.9	7.1	9.6	-
Maize (corn)	3.8	-	5.8	8.4	10.2	12.7	14.4	18.8
Oat	-	5.7	-	8.0	9.6	11.8	13.8	18.5
Pea	5.4	-	7.3	8.6	10.1	11.9	15.0	-
Rice	4.6	5.6	6.5	7.9	9.8	11.8	14.0	17.6
Sorghum	-	6.4	-	8.6	10.5	12.0	15.2	18.8
Squash	3.0	-	4.3	5.6	7.4	9.0	10.8	-
Tomato	3.2	-	5.0	6.3	7.8	9.2	11.1	-
Watermelon	3.0	-	4.8	6.1	7.6	8.8	9.0	-

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Visit workingfood.org/seeds for many more resources on saving seeds in Florida.

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This publication is one in a series of seed saving guides prepared for Florida farmers as part of a SARE Education Grant in 2023-2024 that allowed us to work closely with farmers to adopt seed saving practices on their farm. We are grateful for SARE's support of our project entitled, "*Local Food Needs Local Seed: Increasing Production and Use of Locally Adapted Seed with a Farm to Community Network*". More information about this project can be found on Working Food's website blog.

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