Assembling Seed Moisture Testers, Seed Dryers, and Cone Dryers From Repurposed Components

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Abstract

Accurately determining seed moisture and efficiently drying seeds, cones, and fruits is a critically needed capacity for seed management. In this article, instructions are provided to make a moisture test chamber for easily assessing seed moisture content with a handheld hygrometer. In addition, instructions are given for assembling pressurized dryers for seeds, cones, and fruits. By using repurposed materials, cost and assembly time are minimized and assembly requires only basic mechanical skills and simple tools. Because of the size of the components used, the dryer is best suited to small seed lots weighing less than 100 lb (45 kg). Basic instructions for using the hygrometer, test chamber, and dryer are also provided. Portions of this article were published previously in Karrfalt (2013).

Seeds and Moisture

Moisture is the single, most important factor affecting the viability of seeds in short- and long-term storage (Justice and Bass 1978, Bonner 2008) because high moisture leads to a higher respiration rate, increased microorganism growth, and, in extreme cases, premature germination. These negative effects are further aggravated by higher temperature. Low moisture, on the other hand, lowers respiration and inhibits microorganism growth. When seeds have low-moisture contents, they can even endure short periods of elevated temperature with little measurable loss to viability.

Recalcitrant and orthodox are the two basic types of seeds in regards to moisture relations (Roberts 1973). Recalcitrant seeds are those that must maintain moisture contents in the range of 25 to 45 percent, depending on species and genotype, to maintain viability. Recalcitrant seeds are common with tropical species and retain viability for only a few days, weeks, or months (Luna and Wilkinson 2014). By contrast, orthodox seeds are those that can sustain drying to moisture contents less than 10 percent and not lose viability. Orthodox seeds can maintain viability for long periods of time when stored under low-moisture content. Therefore, it is necessary to understand how to control seed moisture at all stages of seed handling from harvest to sowing. A complete discussion of seed moisture and seed storage is found in Bonner (2008). The methods and equipment described in this article are for reducing and measuring seed and fruit moisture for orthodox-seeded species.

Orthodox seeds are dynamic in relation to the moisture in their environment. That is, when more moisture is in the environment than inside the seeds, moisture will move into the seeds. Conversely, when seeds have more moisture than the surrounding environment, moisture will move out of the seeds. This gain and loss of seed moisture goes on constantly until the environment becomes stable and seeds equilibrate. In a stable high humidity, seeds will equilibrate to that high-moisture content, and at a stable lower relative humidity, the seeds will equilibrate to the lower moisture content. When seeds have reached this stable state with the environment, they have achieved equilibrium moisture content (Bonner 2008). This equilibrium moisture content corresponds to a specific relative humidity that is called the equilibrium relative humidity, or ERH, when moisture is neither gained nor lost. The general relationship of ERH to seed moisture content is shown in figure 1. The use of ERH to manage tree seed moisture has been described by Baldet et al. (2009) and Karrfalt (2010).

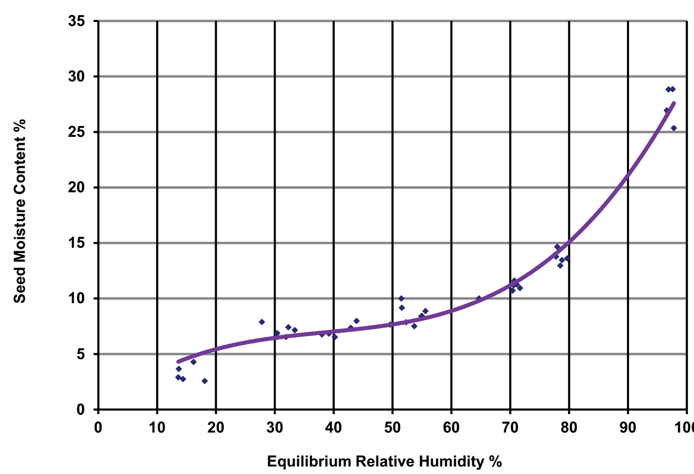

Figure 1. The relationship of seed moisture content with equilibrium relative humidity.

Determining Seed Moisture Using a Hygrometer

Because of the strong relationship between seed moisture content and ERH, it is possible to accurately assess seed moisture status using a hygrometer. Optimal moisture content for storing orthodox seeds is between 5 and 10 percent, which corresponds to an ERH of 30 to 50 percent (Bonner 2008). To allow for errors in measurement and accidental increases in seed moisture, it would be safe to use 30 percent ERH (equivalent to about 6 percent moisture content) as a target to which seeds should be dried to preserve maximum viability. With a compact electronic hygrometer (figure 2), it is possible to rapidly, accurately, and nondestructively determine the ERH of any orthodox seeds. Reliable digital hygrometers range in price from $200 to $600 and are available from various suppliers.

The environment is generally the greater determinant of ERH of seeds. In a small, confined space, however, the situation can reverse and the seeds can dominate the relative humidity of the air. Such is the situation in a sealed jar that is at least half full of seeds. With this quantity of seeds, the loss or gain of moisture with the air will be too small to measurably change the seed ERH. Seeds having a high-moisture content will create high humidity in the jar, and seeds with a low-moisture content will create low humidity in the jar. Thus, ERH in the jar will equal the ERH of the seeds. The sensor of the hygrometer inserted into the jar can measure the ERH.

Any recycled plastic jar with a tight lid can be used for this test (figure 3A). Simply make an opening in the jar lid that closely matches the diameter of the hygrometer probe to create an airtight seal between the lid and the probe. Figure 3B shows how to assemble the hygrometer and test chamber.

Figure 2. Hand-held hygrometer for measuring relative humidity in drying area and equilibrium relative humidity of seed samples. (Photo by Robert Karrfalt)

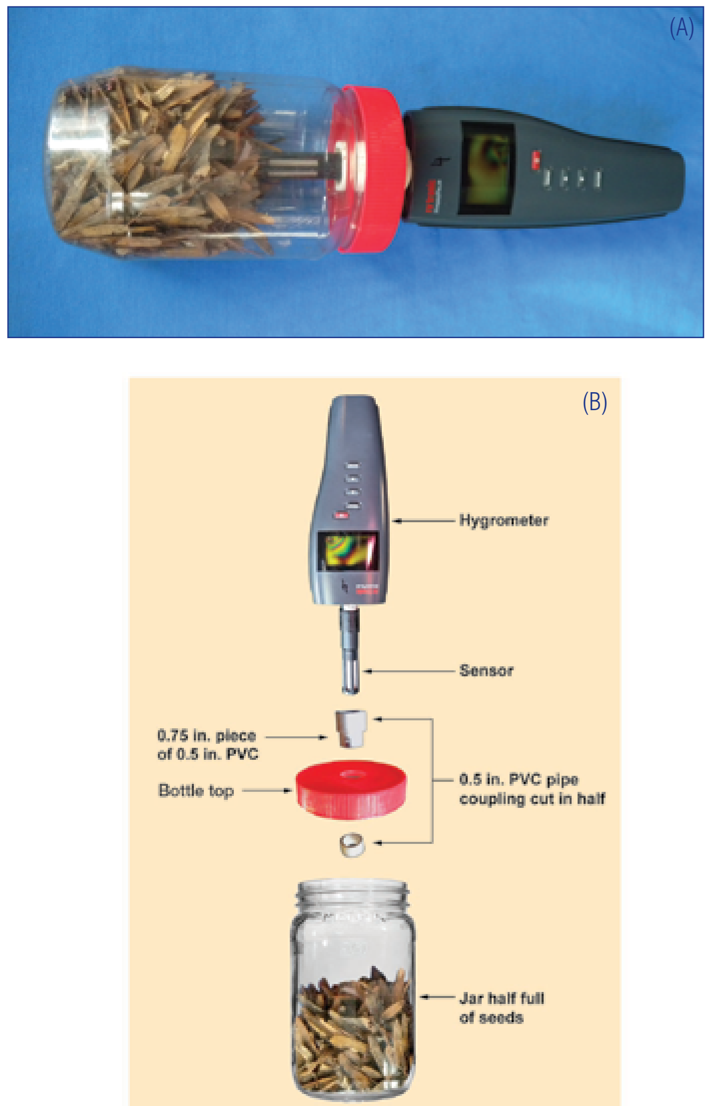

Figure 3. (A) Hygrometer inserted into closed jar to measure the equilibrium relative humidity of a seed sample. (B) Schematic representation of the hygrometer, insertion port, and sample jar. (Photo by Robert Karrfat and illustration by Jim Marin)

The parts include a 0.75-in (1.9-cm) long piece of 0.5-in (1.3-cm) polyvinyl chloride (PVC) pipe and a 0.5-in (1.3-cm) PVC pipe coupling, cut in half. The exact size of the fittings chosen must match the particular hygrometer used. In this example, the probe of the meter shown had to be shimmed out using a few wraps of electrical tape to make a secure fit with the pipe fitting (figure 2). After it is assembled, fill the jar half full of seeds, screw on the lid, and allow the sample to come to equilibrium (a steady reading on the hygrometer). If in doubt about whether or not the sample is at ERH, leave the jar closed and retake a reading in a few hours. If the second reading is different than the first, repeat the process until two consecutive observations are equal. When the reading remains unchanged, the seeds are at equilibrium. The hygrometer should be periodically compared with traceable standards that are usually available from the meter vendor.

Drying Seeds in a Pressurized Dryer

Seeds, cones, or fruits kept in a mass, such as contained within a mesh bag, will dry only at the surface. Therefore, these materials are frequently spread in very thin layers or stirred often so that all the material spends some time exposed to the air and can dry. The seeds are spread in thin layers by placing them on sheets or in screen bottom trays. This approach requires relatively large drying areas. To reduce the work area needed, one variation is to put the trays in a rack and blow air across the trays. Food dehydrators or egg incubators have been used to dry seeds also, but their use usually means the seeds have to be stirred periodically by hand. If air is forced up through the seed mass from the bottom, however, all seeds can be dried without any stirring, in a compact space, and often more rapidly. The apparatus for drying seeds in this manner is called a pressurized dryer.

Pressurized dryers have been made in various configurations and capacities, but all use the same principle of placing seeds in a container with air-tight sides in which dry air is forced upward through the seeds. In larger forest tree seed extractories in the United States, a version of the pressurized dryer consisted of stacks of trays 4-ft (1.2-m) wide, 8-ft (2.4-m) long, and 1-ft (0.6-m) deep. These trays are handled by forklifts and are very efficient for very large volumes of cones. For smaller volumes of material, a pressurized drier can easily be constructed (figure 4) using off-the-shelf components (table 1). The main parts are a 5-gal (19-L) bucket, paint strainers, and a small electric fan. The mesh bottoms of the paint strainers used as trays come in different sizes, described in more detail in the following section.

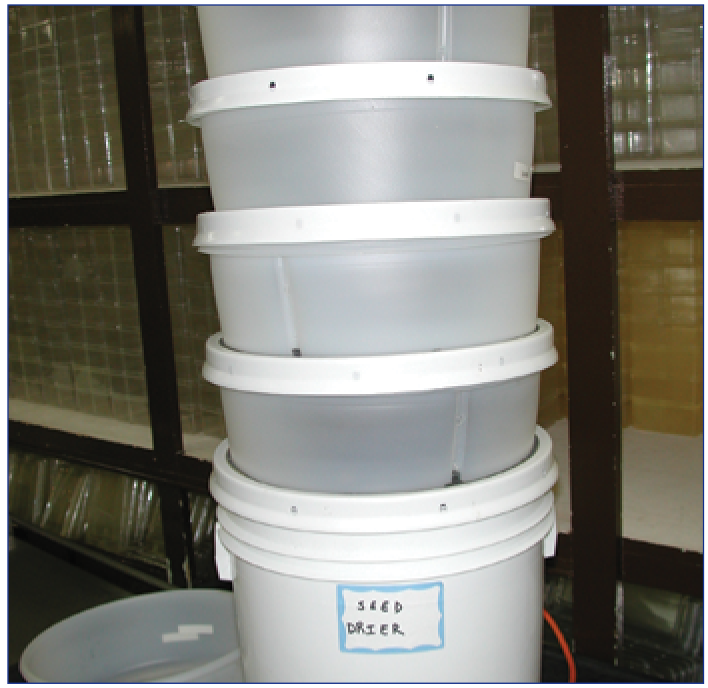

Figure 4. Pressurized seed dryer made from a 5-gal (19-L) bucket, paint strainers, a furnace motor, and other readily available parts. (Photo by Robert Karrfalt)

Table 1. Specifications and possible sources for parts needed to make the pressurized seed dryer.

Item	Specifications	Approximate cost	Possible source(s)
Paint strainer	EZ Strainer 600, 400, 100 mesh (larger number is larger opening)		Internet vendors and local paint supply company
	5-gal (19-L) bucket size 55-gal (208-L) barrel size	$5 ea $12 ea	
5-gal (19-L) bucket	New or used, clean	$0 to $5	Hardware store and recycle bin
5-gal (19-L) pail lid	New or used, clean	$0 to $2	Hardware store and recycle bin
Blower motor	Induced draft, operates at 1.5 to 2.0 in (3.8 to 5.0 cm) of water column (wc) minimum (e.g., Dayton 4C723)	$125	Grainger.com Heating and air conditioning supply store
Extension cord	6 to 10 ft (1.8 to 3.0 m) long, 16 wire minimum	$5	Local hardware
Nonmetallic cable connector	3/8 in (0.95 cm)	< $1	Local hardware
Two wire nuts	For number 16 wire	$2	Local hardware
Weather stripping	0.25-in (0.64 cm) foam tape	< $3	Local hardware
Pan head screws	Number 10 by 0.75 in (1.9 cm)	< $3	Local hardware
2 by 2 in (5 by 5 cm) wood blocks	2- to 3-in (5.0- to 7.5-cm) long		Wood scrap pile

Assembling the Seed Dryer

The dryer can be easily assembled by following six steps.

1. Place a piece of paper on the side of the blower opposite the motor and make a pattern by tracing the blower inlet and mounting tabs and holes.
2. Cut out the pattern and place it on the bottom of the 5-gal (19-L) bucket (figures 5 and 6). Mark the location of the mounting holes and the inlet of the fan. Be certain the pattern is oriented correctly so that the holes on the pattern match the holes on the fan.
3. Drill out the mounting holes with a 0.25-in (0.63-cm) twist drill and carefully cut out the fan inlet opening using a sharp utility knife.
4. Use #10 by 0.75-in (1.9-cm) pan head screws to mount the fan motor by driving them into 2- by 2-in (5- by 5-cm) wooden blocks that will be the legs of the dryer. The type of fan is an induced draft blower for high-efficiency furnaces. It was chosen because it will operate at a high static pressure. A high static pressure in this case is approximately 1.5 to 2.0 in (3.8 to 5.0 cm) of water column that is usually shown in blower specifications as "wc." Trays full of seeds will create a strong static pressure, and if the fan is not built to operate at high static pressure, it will burn out. We have used these fans in seed dryers continuously for several weeks at a time and none have burned out.
5. The drying trays are tapered and will not form a tight seal between trays unless a collar is put between them. This collar is made from the bucket lid. Cut out the center of the lid leaving about 2 to 3 in (5.0 to 7.5 cm) of the lid around the edges. Installing 0.25-in (0.64-cm) foam weather stripping around the lid (figure 6) makes the seal complete.

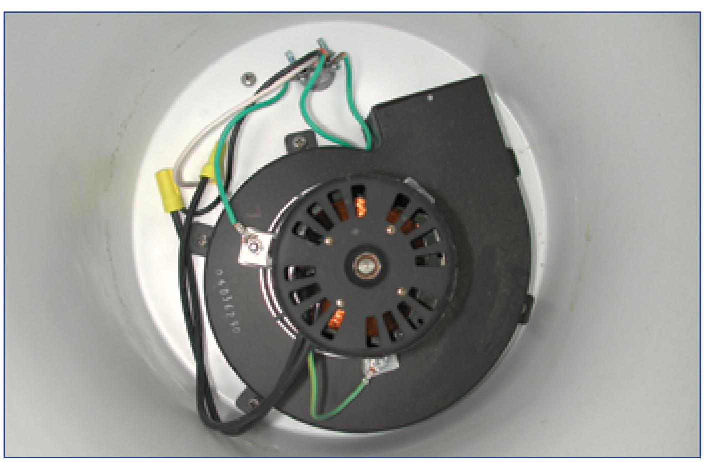

Figure 5. Placement of the induced draft blower and wiring in the bottom of the 5-gal (19-L) bucket. (Photo by Robert Karrfalt)

6. The power cord to the fan is a 6- to 10-ft (1.8- to 3.0-m) long, 16-gauge wire extension cord. Drill a 0.5-in (1.3-cm) hole in the bottom of the bucket and put a nonmetallic cable connector in it to secure the power cord to the dryer bottom (figure 5). Cut off the female end of the power cord, feed it through the connector, and attach the exposed wires to the wires of the blower motor with wire nuts. Obtain assistance in wiring the dryer if you are unfamiliar with electrical wiring.

Using the Dryer

The smallest seeds require trays with 100-mesh bottoms, while larger seeds can be dried on two larger sizes, 400- and 600-mesh bottoms. Using the largest sized mesh that does not let seeds fall through minimizes the resistance of the air movement and allows more seeds to be placed on the dryer at one time. The strainer mesh size needs to be adapted to each seed processor's needs.

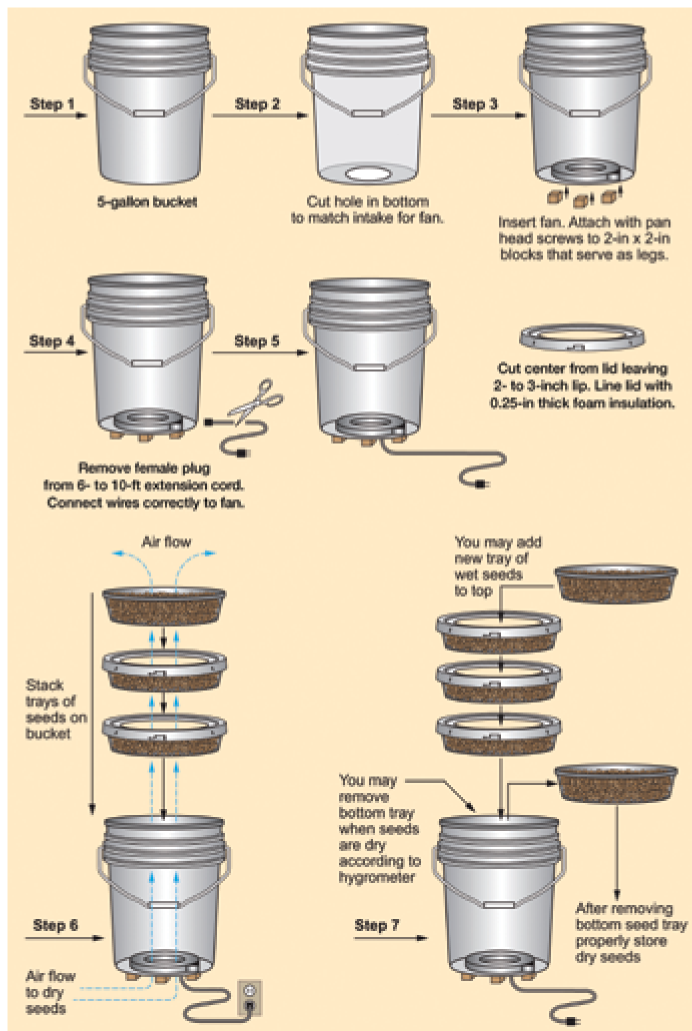

Figure 6. Steps for building and operating a seed dryer. (Illustration by Jim Marin)

The trays can be either completely or partially filled with seeds. When a small amount of seeds are dried in a single tray, it is usually necessary to place another tray over top of the one holding the seeds to keep them from blowing out. Small quantities of seeds, or extremely small seeds, could also be kept in bags with fine mesh and placed inside the tray. Additional weight might also be needed to keep this cover tray in place, but in doing so, do not block the airflow completely. When drying large quantities of seeds, trays may be stacked five or six high before the pile becomes unstable. As long as a gentle airflow is felt coming out the top of the stack, the stack is not too tall.

When stacked, the seeds in the bottom tray will dry first, then the seeds in the middle trays, and finally the seeds in the top tray. The position at which the seeds have come to equilibrium with the dry air is called the drying front. Seeds beneath that front (closer to the fan) are dry, but seeds farther away (over top of it) are still drying. Use your hygrometer to test whether the seeds are at the desired ERH. After seeds in the bottom tray are completely dry (that is, the drying front has passed the top of the first tray), the tray can be removed from the dryer and another tray of seeds added to the top of the stack (figure 6). Do not place the dry tray at the top of the stack, because moisture will be put back into these finished seeds slowing down the whole process. Removing the bottom tray of dry seeds is only an option, and whether it is removed or left in place does not affect the rate of drying in the other trays. Under good conditions, the full stack of trays will dry overnight (or similar period), and the full stack can be changed out all at once. Because the seeds do not require any stirring during this process, as is the case when air-drying a mass of seeds on a table or the ground, pressurized drying saves labor.

The dryer must operate in a closed room or closet where the air is approximately 30 percent relative humidity. This humidity level is achieved by adding heat when outdoor ambient temperatures are less than 60 °F (15 °C). When temperatures are higher, a dehumidifier (or dehumidifier in combination with an air conditioner) will dry the air. Some ambient conditions are naturally dry and then a closed, conditioned space is not needed. The same hygrometer used to test the ERH of the seeds is used to test the dryness of the air in the drying area.

Larger Dryers

If your situation requires a larger dryer, the paint strainers also come in a 55-gal (208-L) barrel size (figure 7). The plenum in this figure was made of plywood. A whole barrel, or one cut in half, would also work. Note the hole on the side of the plenum to allow air to be pulled in by the blower fan. The blower motor described in the previous section will also work for these larger drying trays. The larger paint strainers usually have less taper than the smaller ones, so a collar may not be necessary to seal the stack.

Figure 7. Pressurized dryer made with 55-gal (208-L) barrel paint strainers. (Photo by Robert Karrfalt)

Drying Time and Storage

Using these dryers, seeds should be dried to safe storage ERH within 1 to 16 hours, depending on the amount of moisture that needs to be removed from the seeds. After the seeds are dry, they must be kept in a dry environment or sealed in moisture-proof containers to maintain their low ERH and their viability (Bonner 2008).

Drying Conifer Cones and Expanding Fruits in a Pressurized Dryer

Pine cones and chestnut burrs are examples of plant materials that expand as they dry. These materials are best dried using the larger strainers. Because these materials are relatively heavy, however, they might cause the large paint strainers to nest too tightly for expansion of the cones or fruits, necessitating a collar like those on the smaller strainers (figure 8). Barrel covers are available that work well as collars, just as the 5-gal (19-L) pail lid worked for the small strainers. Barrel covers are relatively expensive, however. Straight-walled pallet containers are another excellent option. The straight-walled containers come in various sizes. A 24.0 by 15.0 by 9.5 in (61 by 38 by 24 cm) container accommodates 0.25 to 0.50 bushels (8.8 to 17.6 L) of cones or one bushel (35.2 L) of seeds and is easily handled by one person.

Figure 8. The lid of the 5-gal (19-L) bucket should have the center removed, leaving a 2- to 3-in (5- to 7-cm) lip. In addition, attaching 0.25-in (0.6-cm) thick foam insulation will improve the seal between the lid and the paint tray that will sit upon it. (Photo by Robert Karrfalt)

Straight-walled containers have solid bottoms and need to be perforated. Use a 0.5-in (1.3-cm) twist drill to make 25 evenly spaced holes in the bottom of each drying container. This number of holes equals the area of the opening for the blower motor. A cardboard template (figure 9) is useful for placing the holes uniformly. A screen must be placed in the bottom of each drying container to prevent smaller seeds from falling through. Pet-proof, screen-door screen is recommended because of its durability. The screen must be secured to the container using quality packaging or duct tape (figure 10). Glues, cements, or solvent welding cannot be used because the containers are made of high-density polyethylene (HDPE). The physical and chemical nature of HDPE is such that only tape can be used to attach things to it. A fastener such as a pop rivet might also work. The same reasoning is applied when using tape to cover the waffles in the container flanges (discussed in the following paragraph).

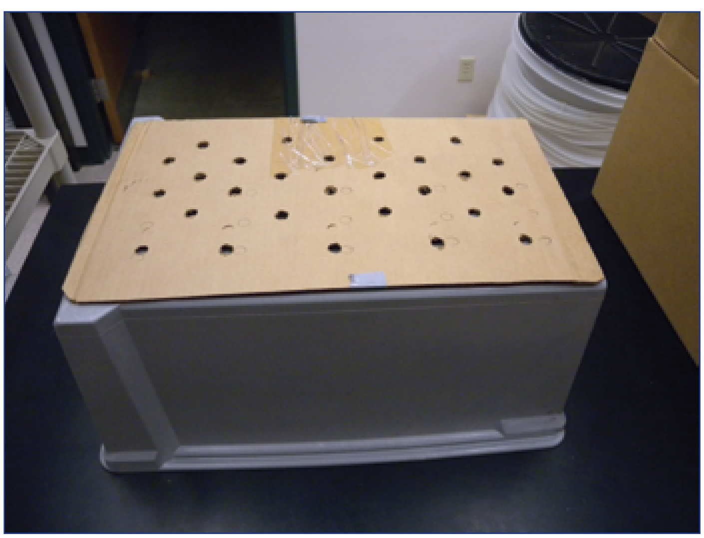

Figure 9. A cardboard template is a quick way to show where to drill the holes across the bottom of the drying boxes. (Photo by Robert Karrfalt)

Figure 10. Box on the left shows pet screen taped to the bottom and box on the right shows hole pattern and foam gasket. (Photo by Robert Karrfalt)

Straight-walled pallet containers have a flange at the bottom that allows two containers to stack securely together while leaving ample room for cone expansion. Although secure for stacking, the connection between containers requires a foam gasket to make an air-tight seal for the dryer (figure 11). The container's flange has a waffle design (figure 12), which requires a covering before attaching the gasket. The covering is a layer of 2-in (5.0-cm) wide tape (packaging or duct tape). To apply the tape, first place the container upside down on a level work surface. Cover one side of the flange at a time by using a piece of tape the length of the flange and attach it to the outside edge of the flange. Carefully fold the tape over the waffles to make a smooth surface and a sharp junction with the side of the container. Finally, smooth the remaining tape against the side of the container. The foam gasket can now be attached to the underside of the flange. The most suitable foam gasket seems to be the foam sealer for pick-up truck body caps. Other foam weather stripping is usually too stiff or too soft. Not having to use a collar between containers is an advantage while loading and emptying containers because only one item, the container, is handled and not two, container and collar. Fewer movements can save much time in a busy cone-processing day.

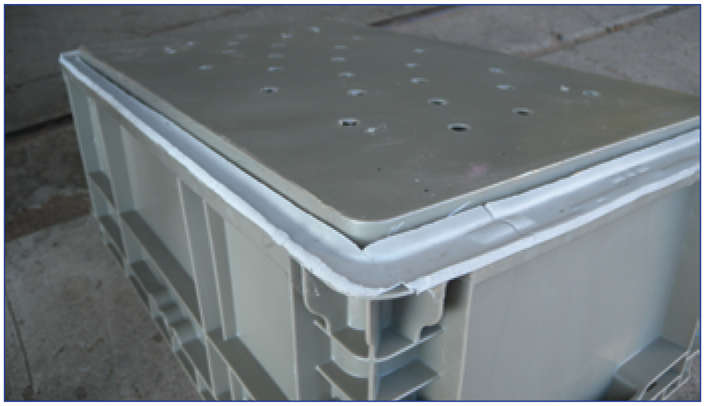

Figure 11. A foam gasket is needed on the flange on the bottom of the drying box to form an airtight seal. (Photo by Robert Karrfalt)

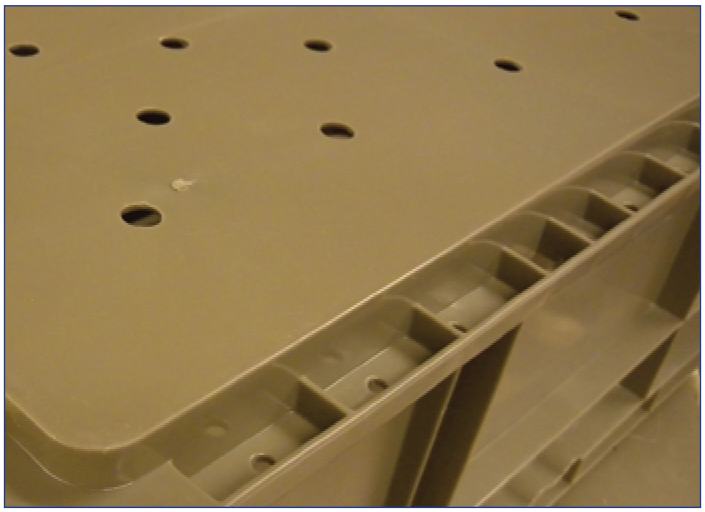

Figure 12. The flange on the bottom of the drying box has a waffle design that must be covered with tape before applying the foam gasket shown in figure 11. (Photo by Robert Karrfalt)

The blower motor can be mounted in a container at the base of the stack of drying containers in the same way as it was mounted in the 5-gal (19-L) pail. Unlike seeds, the container should be filled only half way when drying cones or fruits to allow for expansion during drying. Drying time is 1 to 16 hours depending on the amount of moisture that needs to be removed from the plant material. After the cones or fruits are dried, they are ready for seed extraction. Seed extraction and cleaning are covered in detail in Karrfalt (2008).

Conclusions

By constructing and using the equipment described in this article, it is possible to have advanced seed technology methods for drying seeds and testing their moisture status. Seeds, cones, or fruits can be dried rapidly, using minimal labor and a minimal amount of work area. By deploying repurposed components, a minimal amount of time and mechanical abilities is required to assemble the equipment. Cost is also kept low because all components are mass produced for other purposes. The end result is maximum seed quality at minimal labor and material costs.

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