

A SIMPLE AND SAFE METHOD FOR RAPID DRYING OF PLANT SPECIMENS USING FORCED-AIR SPACE HEATERS

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ABSTRACT. We describe the use of forced-air space heaters for drying herbarium specimens with a setup that is simpler, lighter, safer, and more economical than most previously described portable dryers. We have tested this method during collecting trips in the tropics with excellent results. Access to electricity and a rain-protected site are the only requirements. Temperatures inside the press reach ca. 63 and 106°C with the space heater model we use (Lakewood® 707) under low (750 W) and high (1500 W) wattage modes, respectively. At the low and high wattage modes, herbaceous samples can be dried in 5–6 or 2–3 hours, woody samples in 9–12 or 5–7 hours, and succulent material in 18–24 or 8–12 hours of continuous operation. The quality of the specimens produced with this method is very high; even when dried with the high wattage mode, they do not show signs of burning, and most specimens dried with the low wattage mode retain their natural colors and are often suitable for later extraction of DNA.

Key words: field methods, herbarium specimens, portable dryer, space heaters

RESUMEN. Describimos el secado de muestras de plantas para herbario mediante el uso de calentadores eléctricos de aire forzado, con un equipo más sencillo, liviano, seguro y económico que el de otras secadoras portátiles descritas hasta el momento. Hemos usado éste método durante viajes de recolecta en el trópico con excelentes resultados. Los únicos requisitos son el acceso a electricidad y un sitio protegido de la lluvia. Con el modelo de calentador que utilizamos (Lakewood® 707), la temperatura dentro de la prensa alcanza 62 y 106°C en las modalidades de 750 y 1500 vatios, respectivamente. Con las modalidades baja y alta, respectivamente, muestras herbáceas pueden secarse en 5–6 o 2–3 horas, muestras leñosas en 9–12 o 5–7 horas, y muestras suculentas en 18–24 o 8–12 horas de operación continua. Los especímenes producidos con éste método son de muy buena calidad; no hay signos de quemadura ni siquiera con el secado en modalidad alta, y muchos especímenes secados con la modalidad baja retienen sus colores naturales y pueden usarse para la posterior extracción de ADN.

INTRODUCTION

The preservation of vascular plant samples in the field for preparation of herbarium specimens has been a subject of continuous concern (Bridson & Forman 1992). A widely used method involves temporary preservation with 50–80% ethanol or 30% formaldehyde in sealed plastic bags, but this requires transportation of considerable amounts of liquid and substantial messy work and possible exposure to toxic fumes during the separation and drying of specimens. These fluids also cause discoloration and destroy DNA, making the specimens less valuable. Field drying, therefore, is highly desirable, and numerous techniques and devices have been presented over the years (e.g., MacDaniels 1930, Camp 1946, Lundell 1946, Steyermark 1947, Beard 1968, Jenne 1968, van der Merwe & Grobler 1969, Botha & Coetzee 1976, Hale 1976, Croat 1979, Perdue 1982, Sinnott 1983, Liesner 1990, Bridson & Forman 1992, Eggl & Leuenberger 1996). Except for drying plants in

a press tied to the roof of a moving vehicle in dry weather (Liesner 1990), however, all of these methods require the custom manufacture of equipment that is often heavy, bulky, or brittle, and/or the handling of potentially hazardous materials or open flames.

Here, we describe a much simpler, safer, and highly efficient portable dryer that uses commercially available forced-air space heaters (small electrical appliances with a fan and heating elements, designed for warming up small to medium-sized rooms). The only other items needed are a piece of cloth (minimum dimensions 0.7 × 1.5 m but preferably larger), two pairs of wooden plant press frames, newspaper, corrugated herbarium cardboards and straps (FIGURE 1A). Optional but desirable additional items include a metal rack for hanging file folders (of the kind used in file cabinet drawers), an electrical extension cord, and a two-pronged outlet plug adapter (see below). The entire setup is much lighter, economical, and easier to install than that of most previously presented methods for field drying, and all the items (except the space heater and possibly the cloth) are normally

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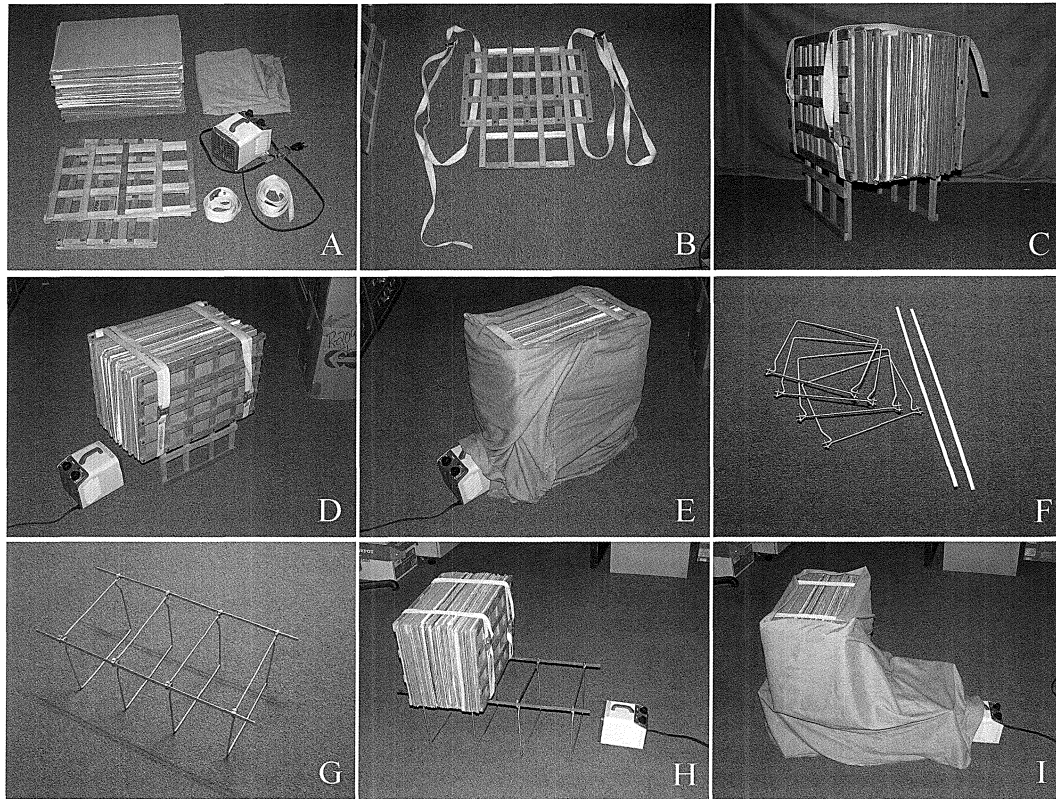


FIGURE 1. Two alternative methods for assembling a portable plant specimen dryer. Method 1 (A–E): **A.** Items needed, clockwise from upper left: corrugated cardboards and newspaper, piece of cloth (folded), space heater (Lakewood® 707), straps, and four wooden press frames. **B.** Proper position of the first two frames. **C.** Assembled press with inner pair of frames used as stilts. **D.** Proper position of space heater with respect to press. **E.** Cloth wrapped around press and front of space heater. Assembly Method 2 (F–I): **F.** Metal rack partially disassembled for transportation. **G.** Assembled rack. **H.** Press placed on top of rack, and space heater properly positioned. **I.** Cloth wrapped around press, rack, and front of space heater. See text for details.

found in any herbarium. The space heater also is useful during field trips for drying wet clothes or shoes, and for warming up cold rooms at high elevations.

MATERIALS AND METHODS

We use the Lakewood® 707 utility space heater (Lakewood Engineering & MFG Co., Chicago, Illinois, USA, available at www.heatersandfans.com). This model is small (14 × 13 × 17 cm), light (1.55 Kg), and relatively inexpensive (but price can vary depending on the season). It has a sturdy metal outer frame, an overheating shutdown system (restarts after it cools down) and an internal backup safety fuse, a thermostat control, and a switch for either fan-only, low (750 W) or high (1500 W) wattage modes. Detailed specifications are available through the company's website (www.lakewoodeng.com).

We have used several of these units and have never experienced malfunctioning even after several weeks of daily use. We have no commercial ties with the manufacturer or distributors, and mention them only as a convenience for interested potential users, as we consider this particular model extremely reliable. We have not conducted extensive comparisons with other brands or models, and others might also be suitable for this purpose. Whichever space heater model is used, it must have all the controls and air-intake vents toward the back of the unit, must have a metal (not plastic) outer frame, should be equipped with an overheating shutdown system, and should be no taller than 20 cm (so it blows the hot air to the space under the press and not directly to the cardboards; see below).

The Lakewood® 707 space heater works with 120 Volts A.C. If this unit has to be used in an

electrical network of 220–240 Volts, a voltage transformer is necessary (not a voltage converter, as these are not designed for continuous operation; see <http://users.pandora.be/worldstandards/electricity.htm>). When collecting abroad, find out in advance the electrical network voltage of the country to be visited, and get an appropriate voltage transformer if necessary.

The most appropriate place for the dryer might be some distance away from the nearest electrical outlet, and we always carry 5 m electrical extension cords. The extension used must be a 3-wire cord with a grounding (type A) plug, be classified as No. 14 minimum on the American Wire Gauge (AWG) system, and support not less than 1875 Watts. Each extension cord must be dedicated (one per heater with no other appliances plugged in at the same time) and should never be used in tandem, to prevent overheating and accidental fire. We recommend extension cords designed for outdoor use; they are heavier but more resistant to wear and tear. More information about extension cord types and safety guidelines for their use can be found online at www.ul.com/consumers/cords.html. Three-slot grounded (type A) electrical outlets are not universally available, and we carry two-prong (type B) plug adapters (one per heater). These adapters must be rated 15 Amps or greater. These electrical requirements are specific for the Lakewood® 707 space heater, as per the manufacturer's specifications. Other brands and models might have different requirements, and these should be followed to prevent overheating of the unit and accidental fire.

Assembly Methods

This forced-air plant specimen dryer can be assembled in two ways.

Method 1. Two pairs of wooden presses (four frames) are used. After building a stack of plant specimens in newspapers intercalated with cardboards, one pressing frame is laid flat on the ground or on a table, and a second frame is placed perpendicular but centered on the first, so that one of the short sides of the second frame is aligned with one of the long sides of the first (FIGURE 1B). The stack of cardboards and specimens is then placed on top and aligned with the first frame. The other two frames are put on top of the stack by inverting the order of the first two frames. The straps are placed around the outer frames and partially tightened, leaving enough slack for straightening the cardboards by turning the entire press on its back and on its side; then the straps are tightened further. The inner pair of frames now act as supporting stilts

that raise the rest of the press 15–20 cm from the ground (FIGURE 1C). After finding a suitable place for the dryer (see below), the space heater is placed facing one of the sides of the press unobstructed by the stilts (FIGURE 1D), and the piece of cloth is wrapped as a skirt around the sides of the press and the front of the space heater (FIGURE 1E). The lower edge of the cloth has to rest on the ground to minimize escape of the hot air from the bottom. The control panel and air-intake vents of the space heater must be left out of the skirt, and enough open space has to be left on top of the press to let the hot air flow freely through the corrugated cardboards. The cloth can be held firmly in place by hooking its two upper corners with the press straps, or a third strap or string can be put around the upper part of the press. Care should be taken that no part of the cloth hangs in front of the heater outlet, so that the hot air flows unobstructed into the closed space under the skirt.

Method 2. The second method of assembling the dryer involves one pair of wooden presses (two frames) and a metal rack of the type used for hanging file folders in cabinet drawers. For ease of transportation, the rack can be partially disassembled when not in use by untightening the screws that hold the longitudinal bars in place (FIGURE 1F, G). The press, prepared using the two frames and straps, is placed on top and toward one end of the assembled rack (if shorter than the rack), and the space heater is placed adjacent to the opposite end, facing the space under the rack (FIGURE 1H). The cloth is then wrapped as a skirt around the press, rack, and front of the space heater (FIGURE 1I), following the same procedure and precautions as above.

Assembly and Drying Time

The time necessary for assembling the dryer using either mode is similar (ca. 5 minutes). The first method is practical for small-volume presses (up to 50 cm thick). The second method is preferable for larger presses, as the weight of the press rests on the rack instead of being held by the tension of the straps. The rack also helps to keep the press together, should it become loose after shrinkage of the specimens, and facilitates flipping the press around for even drying. With the four-frame method, the straps need to be re-tightened after 3–4 hours of drying to prevent the press from sagging and becoming unstable. File cabinet racks are normally $70 \times 31 \times 24$ cm, and presses of considerable thickness can be supported on them. These racks are surprisingly firm and can hold considerable weight, but additional vertical props can be added to the

rack to support a heavy press if necessary (we usually use four props per rack, and the weight of a rack with four props is 1.2 Kg).

When the dryer is assembled, the space heater can be turned on and checked after 10–20 minutes to make sure that the hot air is flowing through the corrugated cardboards. We operate the space heater in the high wattage mode (1500 W) to speed up the drying of succulent material, but the low wattage mode (750 W) is preferable for most other plant samples. Even at the high wattage mode, specimens are never burned (a common problem with convection-type dryers at higher temperatures). If dried using the low wattage mode, specimens tend to retain their natural colors and are often suitable for later extraction of DNA.

The heating elements inside the space heater are protected by a metallic grill, and the hot air is forced horizontally under the press before escaping vertically through the corrugates. Because the space heater is not located immediately under the press, any debris that fall from the press cannot come in contact with the heating elements. Before the use of a rack occurred to us, we had a few instances where a thick press became loose and collapsed during the night. In such cases the space heater typically becomes obstructed by the cloth and overheats, and it automatically shuts down, minimizing the risk of accidental fire.

Because the air-intake vents remain outside of the cloth enclosure, the space heater thermostat does not control the press temperature. If, however, the dryer is placed in a small room (such as a bathroom), the thermostat should be set at the maximum temperature to prevent the space heater from pausing as the room warms up. Windows should be left at least partially open to prevent heat buildup in the room and allow the continuous functioning of the space heater, and to allow the escape of humid air.

To determine the temperatures reached within the press with this method, we assembled a press with corrugated cardboards to 20 cm thick, with a digital probe thermometer inserted in the cardboards. The dryer was installed in a room with ventilation but no major air currents; the initial air temperature was 23°C. With the space heater operating at the low wattage mode (750 W), the press temperature stabilized at 63°C after 2 hours. When the heater was tested with the high wattage mode (1500 W), the press temperature stabilized at 106°C after the same amount of time. These temperatures are well below the ignition thresholds of most solid flammable materials, and the external metal frame of the space heater always remains at a much lower temper-

ature. The risk of accidental fire, therefore, is minimal.

During field trips, we usually collect during the day, press plants in the evening, and leave the dryer working overnight (6–8 hours). In the morning, we set the space heater to fan-only mode for 20–30 minutes to cool down the press, before disassembling it to inspect the samples. Any incompletely dried specimens are put back in the dryer or left aside and added to the next stack of fresh samples at night.

As with other forced-air drying methods, it is better not to use blotters to minimize the number of layers between the plant sample and the hot air flowing through the channels of the corrugated cardboards to maximize the rate of water evaporation (cf. Egli & Leuenberger 1996). It is crucial that the corrugations in the cardboards run widthwise, or the airflow will be obstructed, and the temperature could increase dangerously under the skirt. Deformed or collapsed cardboards should not be used in the dryer, because the corrugations likely are obstructed.

The drying method explained here is similar to the use of a hair dryer described by Egli & Leuenberger (1996), but it is more practical, as no custom-made bag is necessary. It is also safer and more reliable; hair dryers (unlike space heaters) are not designed for continuous sustained operation, nor do they stand steady on the floor. One of us (DSP) once tried to use a hair dryer for preparing herbarium specimens, but the unit burned out after ca. 5 hours.

As with the method described by Egli and Leuenberger (1996), the dryer has to be installed in a rain-protected site with a dry, non-flammable surface (cement or tile floors are ideal). As a general precaution, the dryer should be placed away from any potentially flammable objects and sited with the permission of the building's owner. We have used several different types of cloth for the skirt (most of which are not fire-resistant) without problems. Some heat escapes through the fabric of the cloth, and this seems to prevent excessive heat buildup under the skirt. The use of a completely airtight material for the skirt therefore is not recommended. If the cloth is black, grey, or dark blue, it also can serve as a neutral background for photographing plants, when the dryer is not in use.

Our drying method was developed during several field trips to Costa Rica, Panama, the Dominican Republic, and Ecuador. We have dried more than a thousand collections with this technique, many of them with multiple duplicates. Many of the plants we collect are orchids with succulent pseudobulbs, and typically even these dry completely after 8–12 hours of continuous operation (rarely 24) using the high watt-

age mode (or about 12–24 hours with the low wattage mode). Plant specimens need to be slashed or cut in half longitudinally (and any contents need to be partially scooped out, if the specimen is very thick) to facilitate evaporation. Using the high and the low wattage modes, respectively, herbaceous samples can be dried in 2–3 or 5–6 hours, and woody samples in 5–7 or 9–12 hours of continuous drying.

Before embarking on a collecting trip, we recommend one or two trials of this method to become familiar with the procedures, the space heater, and the drying rates; also for checking that the cloth size is suitable for the expected size of the presses. If the expected daily volume of collections is high, additional sets of space heaters, cardboards, and other items can be taken to the field. If two or more heaters are used at the same time, they should be connected to separate outlets away from each other to prevent overloading the local electrical system. These space heaters are relatively cheap, and at the end of our trips abroad, we donate them to local herbaria along with instructions for their use as portable dryers. We encourage others to do the same.

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