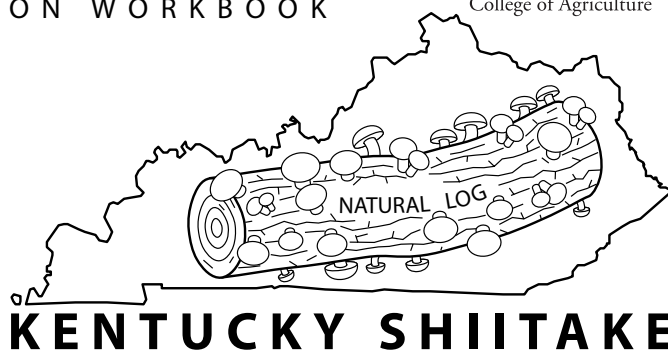


Inoculation

Deborah B. Hill and Marcella Szymanski, Extension Forestry Specialists



Introduction

To begin the process of shiitake mushroom production, you must “sow the seed” just as you would with any other agronomic crop. For shiitake, the “seed” is called *spawn* and consists of the mushroom spores mixed with sawdust (for sawdust spawn) or wood (for dowel spawn) and a little grain to add a higher level of carbohydrate for the organism to feed on. When you buy a package of sawdust or dowel spawn, the spores of the mushroom have germinated and have begun to consume the carbohydrate in the sawdust or wood, making the whole container “active ingredient.”

Shiitake feeds on **newly dead** hardwood logs and is officially known as a white wood-consuming fungus. Organisms that decompose wood and other organic material are very important components of our ecosystems—they are the “garbage collectors” that clean things up and break them down into basic nutrients that can then be used by other organisms.

Shiitake is “planted” into the newly dead hardwood logs by **inoculation**. Once you have inoculated the spawn into the logs, there is **no need to repeat the process**; the shiitake mycelium—the actual organism—will continue to grow until there is nothing left for it to feed on. Because it is a type of rot, logs cut from trees that are badly damaged and that already have a lot of rot in them are not good candidates for shiitake production. Likewise, you **cannot** grow shiitake on dead wood, such as old logs in your yard or woodland. It is recommended that logs be inoculated within two weeks of being cut, and the trees from which they are cut **must have been alive and healthy** at the time of cutting.

Logs

Virtually any variety of hardwood log can be used to grow shiitake mushrooms. Some species, such as birch (*Betula* spp.) and red maple (*Acer rubrum*), are less dense than others and may produce mushrooms more rapidly than varieties such as oak (*Quercus* spp.) or hickory (*Carya* spp.). Some hardwood species, such as walnut (*Juglans* spp.) and black locust (*Robinia pseudoacacia*), are known for their rot-resistant properties and may not produce shiitake successfully or easily. It is important to cut the logs at a time when the bark is securely attached to the tree (see below). Denser tree types may be more reliable producers in the long run.

Shiitake logs will have a productive lifetime of two to five years depending on diameter and tree species. The bark of trees is similar to the skin of animals; it protects the organism from injury and invasion by bacteria and fungi. It is important for the bark to protect the cut logs for the longest time possible.

Timing

Shiitake **can** be inoculated into logs at any time of the year, but the **most effective** times appear to be in the fall when the leaves are starting to drop (mid-October to mid-November) or in the spring when the sap is rising to produce new leaves (mid-February to early April). The **worst** time is when the trees are actively growing (mid-April to mid-July). During the active growth period, the bark tends to be “looser” on the tree. Success with shiitake production demands that the bark be “tight” against the wood of the logs.

Material and Equipment Needs

To ensure success in the shiitake inoculation process, you will need the following items:

- **Logs**—Use hardwood varieties, 3 to 8 inches in diameter, 36 to 48 inches in length (40 inches recommended). These can come from your own land as a result of timber stand improvement or from a few trees removed from your woods. If you do not have woods of your own, be prepared to spend at least \$1 per log for someone else to cut them to your specifications and to deliver them to you. If you get shiitake logs from leftover tops in a logging operation (which is a good option because many large branches are big enough for shiitake logs), be sure that they have been recently cut and have not been sitting on that site for a month or more. Timing is *very* important here. Note that a fringe benefit from disasters such as hurricanes, tornadoes, and ice storms is that a lot of branch wood and small-diameter trees come down all at once, and most people with damaged trees like to get rid of them *immediately*.
- **Work table or sawhorse**—Logs can be heavy and are often not straight, so you will need a secure surface on which to work. X-shaped sawhorses are recommended, especially for drilling, because they hold the logs securely in the upper “V” of the “X.” You can then move the logs to any waist-high table

to fill and wax them. You can also design a table so that you can set up an assembly line with stations—someone drilling at one end, others filling and waxing in the middle, and someone labeling at the other end or off the table completely. One type of table is illustrated in Figure 1. Such tables, including the one illustrated, have notches, or “cradles,” to hold the logs for various operations.

- **Drill** (Figure 2)—The best type of drill to use for a shiitake operation is a *very high-speed* drill (4000 to 8000 rpm). Hardwoods are called that for a reason, and once you start to drill thousands of holes in your logs, you want to be able to do it as quickly as possible; the high-speed drill will make it much easier. A few manufacturers (mostly Japanese) make this type of drill. Although a high-speed drill is expensive (\$200-300), it is a one-time cost, and the drill bits are not terribly expensive to replace.

- **Drill bit**—You will need a drill bit measuring $\frac{5}{16}$ to $\frac{7}{16}$ of an inch in diameter, depending on whether you are using sawdust or dowel spawn. The dowels are very narrow and need a smaller opening. Both types should have a hole about 1 inch deep. The drill bit should have a *stop or collar* on it—set at 1 to $1\frac{1}{4}$ inch—to prevent the bit from going too far into

Figure 1. A design for an inoculation table.

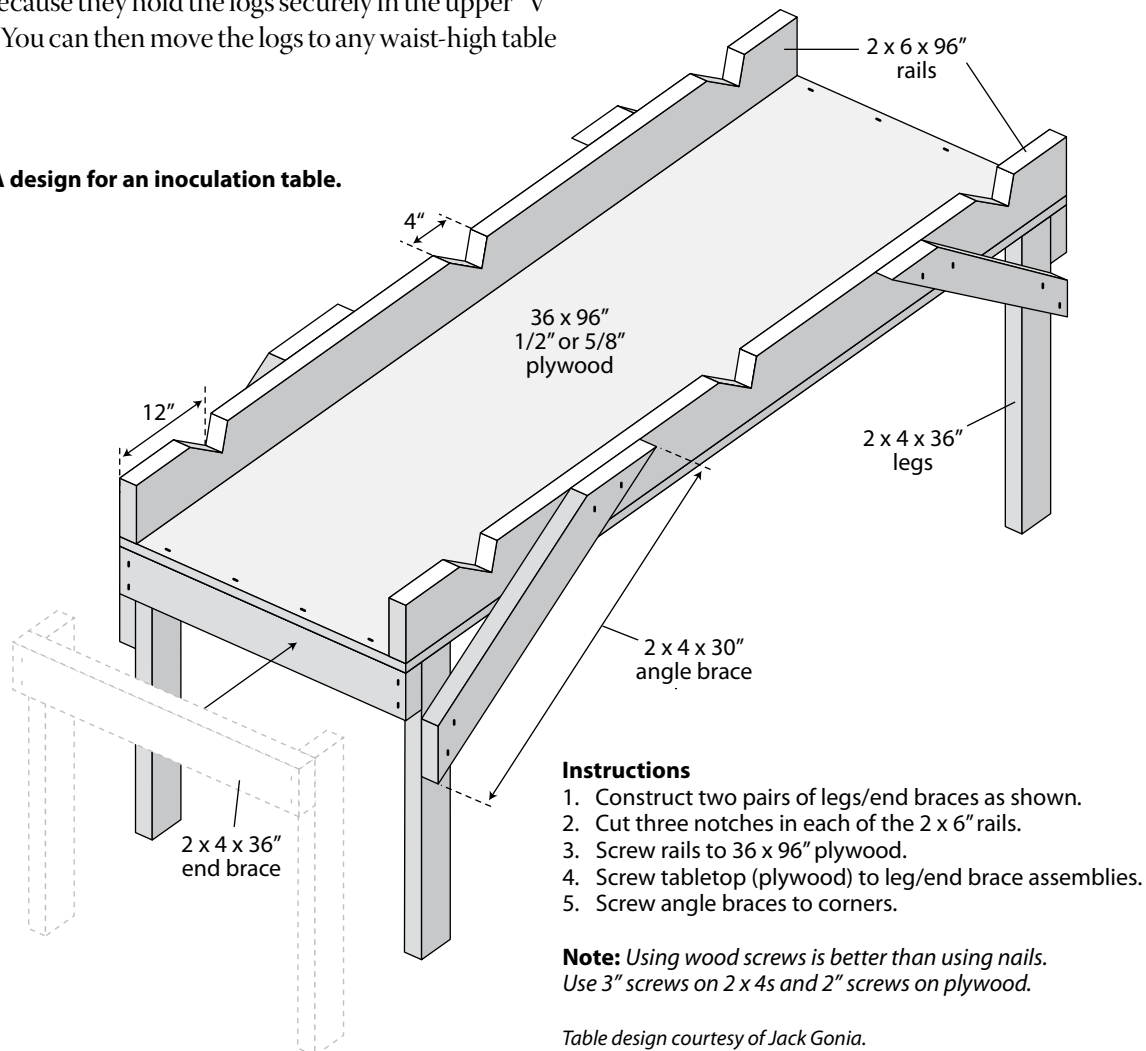




Figure 2. Japanese shiitake drill.

the log. Try to avoid making an air pocket under the dowel spawn in particular because it will make it more difficult for the spawn to grow into the wood. An air pocket under the spawn plug can cause the spawn to lose moisture, something you want to avoid.

- **Spawn**—Decide whether you prefer to use sawdust or dowel (also called plug) spawn (Figures 3 and 4). Both have pluses and minuses to them, so deciding which to use is a personal decision. *Sawdust spawn* is usually a bit less expensive per log and may give you a more rapid and more complete inoculation (see FOR-80, *Spawn Selection*). *Dowel spawn* is much easier to handle and to get into the drill holes but is more expensive on a per unit (and per log) basis. Talk with suppliers. (See FOR-77, *Shiitake Mushroom Production: Step-by-Step in Pictures*, or FOR-89, *Resources*, for lists of recommended shiitake suppliers.) All of the suppliers on these lists are *very* user-friendly. They can tell you how many units of spawn you will need to purchase for the number of logs you plan to inoculate. Remember to tell them the average diameter of your logs and to what length you are planning to cut them.
- **Sawdust spawn inoculator** (Figure 5)—Although it is possible to pack sawdust spawn into drill holes by hand, an inoculator packs it in more efficiently and with less possibility

of contamination. This spring-loaded, tube-shaped piece of equipment costs about \$35 but, as with the drill, probably will not need to be replaced frequently.

- **Rubber or latex gloves**—If you buy sawdust spawn, you will have to break it up with your hands to loosen the block enough to get the spawn into the inoculator and into the holes. Using gloves when handling a lot of spawn 1) prevents skin irritation and 2) keeps bacteria and other organisms on your hands from getting into the spawn. You will have to handle dowel spawn also, but it isn't quite as messy as sawdust spawn. This is one simple way of keeping your inoculation process "clean." It isn't rocket science or brain surgery, but a little common sense and cleanliness goes a long way.
- **Isopropyl alcohol**—This is another item recommended for a "clean" site. It is a good idea to keep a container of alcohol at the drilling site for dipping the drill bit into at the end of every row. This will help prevent contamination inside the holes from various organisms on the outer bark. While you won't be working in a hospital operating room, keeping things as clean as reasonably possible is a good idea when working with an organism that is going to be a food commodity.
- **Wax** (Figure 6)—The preferred type of wax is something called "cheese wax"—a food-grade wax that is used to form the outer covering for such cheeses as Edam and Gouda. This wax is relatively expensive, but you only need to use small quantities for optimal results. It is the wax of choice because it melts at a higher temperature than other kinds of wax and, therefore, does a better job of sterilizing the inoculation sites. It is also a sturdy wax and will stay on the logs for their working lifetime of several years.
- **Container for melting wax** (Figure 7)—The wax needs to be applied when it is in liquid form and very hot. Use a hot plate or some other electrical device to heat the wax. The wax is flammable; therefore, using a heat source without a flame is a good idea. You can use a heavy cast iron pot to melt the



Figure 3. Sawdust spawn.



Figure 4. Dowel, or plug, spawn.



Figure 5. Sawdust spawn inoculator.



Figure 6. Cheese wax for sealing inoculation sites.

wax on a hot plate where the level of heat can be controlled. Heat-regulated electrical appliances, such as deep fryers (pick one up at a garage sale or secondhand store), work well because you can *control the amount of heat* applied and keep the wax at a constant temperature.

- **Wax applicator** (Figure 8)—You can use a baster, as you would use for basting a turkey, but choose one that is heat resistant—either plastic or glass. Do not choose metal because you cannot see what is inside. Small wool-ball daubers, available from suppliers, are another option. They are disposable after use and are not expensive. You can also use natural bristle paintbrushes, but they will eventually burn up in the hot wax; plastic brushes burn up immediately!

- **Labels** (Figure 9)—Your logs will produce for several years, and you may be inoculating more logs annually. It is important to label each log with tree species (e.g., RM for red maple), spawn variety and source (MP510 for Mushroom-people’s #510), and date (month, year) so you can keep them straight. Since you will be working with the same logs over a period of years, long-lasting aluminum tags are recommended. It is possible to use recycled aluminum cans for your labels. Simply rinse out the cans, take off the tops and bottoms, and cut the metal into strips. You can also purchase aluminum tags from the suppliers, along with everything else you need for shiitake production. Aluminum tags are also used because you can “carve” the information into them.



Figure 7. Iron pot (R) for melting wax and metal pan (L) for sawdust spawn.

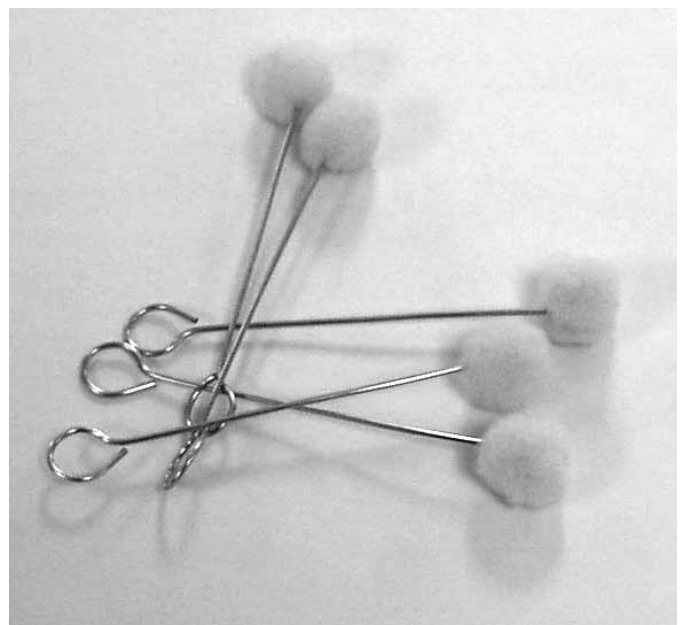


Figure 8. Wax daubers.

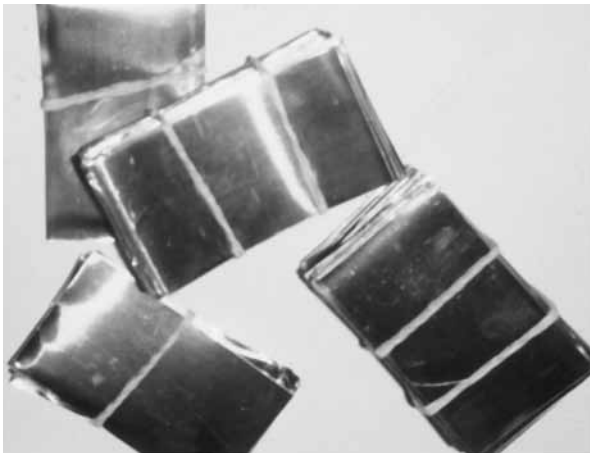


Figure 9. Aluminum labels for logs.

- **Scissors**
- **Large nail or ballpoint pen**—These are used for marking aluminum labels.
- **Small finishing nails or staples (and stapler)**—These are used to attach the labels to the logs.
- **Hammer**
- **Magic Marker or Sharpie pen**—It is important to use a permanent marker.
- **Yardstick or measuring tape**
- **Stiff brush**—This is used for cleaning dirt and debris off logs.
- **Base logs, landscape timbers, bricks or concrete blocks, pallets, or graveled squares**—These materials are used for stacking the finished logs.
- **Shade cloth**—This is a material that comes in different percentages of shades—usually 50%, 75%, etc. For shiitake logs, you would need at least an 85% shade. Probably available at farm supply stores. Buy the amount you need to cover your stacks from a large roll.

Procedure

- Plan your inoculation well *ahead of time*. Order and gather everything so you will be ready on your scheduled date. Most suppliers can send spawn and other equipment or materials within about 48 hours.
- Measure the *diameter* (cross-section) of the small end of each log.
- Estimate that you will drill as many rows of holes as there are diameter inches in the small end of the log.

- Space the drill holes about 6 inches apart within the row and about 1½ to 2 inches around the circumference of the log. Use the permanent marker to indicate where the rows of drill holes should go on the ends of the logs.
- Start your second row of drill holes halfway between the drill holes in the first row so you will end up making a network or diamond pattern of holes around the circumference of the log.
- Drill all the holes in each log at one time. Drill no more holes than you plan to fill that day.
- Move the drilled log to the filling site, and fill all the holes in that log before moving to the next log.
- Move the drilled and filled log to a station/site where the wax is kept hot. Use a “*dab*” (very small amount) of hot wax to cover the drill openings and to seal any fresh cuts, scrapes, or branch stubs on the bark *along the length of the log*. **DO NOT WAX THE ENDS OF THE LOG!** If the wax is the correct temperature (around 400°F for cheese wax but *not* for other kinds of wax), it should foam and sizzle when it hits the surface of the log.
- Once the log is waxed, label it in your own shorthand to indicate the tree species of the log (e.g., RM for red maple, WO for white oak), the type of spawn used (e.g., MP510 for Mushroompeople’s #510, a wide-range spawn, or FFP/WW for Field & Forest Products’ West Wind, a wide-range spawn), and the month and year of inoculation (e.g., 10/09, 2/10). Remember that these logs will produce over a three- or four-year period, and you will want to know which logs are which, especially if you are going to keep production records for each one.
- Stack the logs in a crisscross fashion or in a lean-to fashion (Figures 10 and 11), but make sure the bottom logs are not directly in contact with the soil surface. Either put the bottom logs on blocks, on noninoculated logs, on recycled pallets (usually free), or on beds of gravel. Direct contact with the soil will expose the log to various contaminants and will make a successful shiitake production process more difficult to achieve.
- It will take **6 TO 18 MONTHS** for the logs to incubate to a point where they are ready to fruit into mushrooms. The length of time depends on what time of year you inoculate. Spring inoculation responds more quickly sometimes and will produce mushrooms in the fall of the same year, whereas fall inoculation *may* give you some mushrooms the following spring but maybe not until the following fall or even the second spring. In addition, different types of spawn take different lengths of time to produce (see FOR-80, *Spawn Selection*, for more details).

- Mushrooms like *cool* temperatures and *dampness*. During the winter, make sure the logs do *not* sit in full sunlight and are not exposed to prevailing winds. If there are long periods without rain, snow, or other precipitation, *water* the logs; they can dry out fairly quickly. If they do dry out, the shiitake spawn will be killed. If there is no shade available, cover the stacks loosely with shade cloth. The logs *must* have air circulation, so be sure there is enough space between the top logs and the shade cloth and between the bottom of the stack and the ground for air to circulate.

Conclusion

The information presented is to be used as a general guideline. Unless something is heavily emphasized, there are lots of different ways to get the same results. You are dealing with living organisms, and it is important to keep newly inoculated logs alive and well over the winter. Usually, when the spring warmth and rains begin, the logs wake up and produce mushrooms. Older logs are more resistant to drying and other problems because the organism is working its way deeper into the log and is not so vulnerably close to the bark surface.



Figure 10. Crisscross stacking method.



Figure 11. Lean-to stacking method.

Shiitake and Wild Rice Pilaf

4 ounces fresh shiitake mushrooms, sliced
1 clove garlic, minced
2 tablespoons olive oil
2 cups cooked wild rice (1 cup rinsed raw wild rice cooked in 2 cups water or broth for 30 minutes)
 $\frac{1}{2}$ cup toasted walnut pieces
 $\frac{1}{4}$ cup green onions, sliced
1 tablespoon grated lemon peel

1. In a skillet, slowly sauté mushrooms and garlic in oil over medium to low heat until tender (1 or 2 minutes).
2. Add rice, walnuts, onions, and lemon peel, mixing to blend.
3. Season with salt and pepper.
4. Heat entire mixture to warm through.

Yield: 4 portions.

Mention or display of a trademark, proprietary product, or firm in text or figures does not constitute an endorsement and does not imply approval to the exclusion of other suitable products or firms.