



# Agroforestry Notes

USDA Forest Service • USDA Natural Resources Conservation Service

AF Note — 13

July, 1999

## Farming Exotic Mushrooms in the Forest

### Introduction

One income opportunity derived from forest farming is the production of exotic mushrooms. Many of these edible mushrooms, such as shiitake (*Lentinula edodes*), maitake (*Grifola frondosa*), lion's mane (*Hericium erinaceus*), and oyster (*Pleurotus spp.*) feed on the cellulose and lignin in wood. Although a significant volume of these mushrooms is produced under artificial conditions on a substrate of sawdust, grains and other supplements, production on logs results in firmer texture and more flavor.

Production of high-value mushrooms on small diameter logs of almost any hardwood species enables a private forest landowner to utilize forest thinning residue. In the past ten years or so, markets for shiitake mushrooms have remained stable, with wholesale prices for top quality mushrooms ranging from \$4 to \$12 per pound, depending on supply and demand.

### Exotic Mushrooms Commonly Farmed in the Forest

**Shiitake** - Gourmet mushrooms that look like many other stalked mushrooms, have a slight garlicky taste, are honey brown to almost black on top with white gills underneath.

**Maitake (also called hen-of-the-woods)** - Gourmet mushrooms which tend to grow in large masses of overlapping scales, similar to turkey feathers, are brownish-gray in color with light gray to cream edges.

**Lion's mane (also called pompom)** - Gourmet mushrooms which grow to resemble a pompom, with many "spikey" projections downward on a single large (greater than a six inch) mass, cream to white in color.

**Oyster** - Gourmet mushrooms which come in a wide array of colors from cream to various pastels, which can grow in a stalked form, like shiitake, or in more of a mass form, like lion's mane.

### Materials and Equipment

#### High speed drill

Use drill bits sized for the kind of spawn or inoculation tool used (see below), and a drill stop to prevent drilling too deeply into the wood.

#### Spawn

This material comes in two forms, sawdust spawn and dowel spawn. Both include spores of the desired mushroom species which have been "run" through either sawdust or small wooden dowels (about one inch by 3/16 inch). Grain is added to the sawdust mixture as a nutrient and carbohydrate source.

Sawdust spawn is usually sold by the pound and dowel spawn in containers of 100.

Standard units (enough to inoculate 10 to 20 logs) cost around \$20. A rule of thumb is that shiitake inoculation will cost \$1.00 to \$1.50 per log. In addition to its two physical forms, shiitake spawn also comes in different varieties - warm season, cool season, and wide range (referring to the climatic conditions under which the strain is most likely to fruit). Growers should consider a cold weather strain for growth in the spring or fall and a warm weather or wide range strain for summer. New growers should experiment with different types to see which work best under their unique conditions. Costs for spawn of different mushroom species vary - spawn for oyster and lion's mane may cost closer to \$2.00 per log, and maitake, \$3.00 per log. When ordering spawn, it is suggested that at least two strains of spawn be used.

### **Freshly cut logs**

Logs should be cut no more than a few days before inoculating, and the trees from which the logs are cut should be alive at the time of cutting. Inoculating into freshly cut logs should ensure that the fungus which begins the breakdown process of the log is the desired mushroom species and not something else. Recommended log diameters are three to eight inches; recommended lengths are two to four feet. Logs smaller than three inches in diameter can dry out very quickly; logs greater than six inches in diameter can produce mushrooms over a longer period of time but require more inoculation sites per log to compensate for the greater diameter. Maitake can also be inoculated directly into the stumps of freshly cut trees. Mushroom logs require a lot of handling, so it is important to note that a log four feet by eight inches can weigh up to 80 pounds! Oaks have proven to be some of the most productive species for exotic mushrooms, and a wide variety of other hardwood species are also acceptable.

### **Cheese wax or other food-grade wax**

When spawn is inoculated into the logs, the inoculation sites and any other raw wood sites (cuts, branch stubs, scrapes, possibly the ends) should be coated with hot (400 degrees F.) wax. This sterilizes the surface of the site against any competing fungi or bacteria and prevents water loss, maintaining proper moisture content.

- **Heat source for the wax** - anything that will melt the wax and keep the wax hot during the inoculation step. Possibilities include a heavy duty pot on a camping stove or other heat source, or a self-contained electric deep fryer.
- **Applicators for wax** - metal or glass turkey basters work best, ideally with a steel wool screen in the tip. Most paint brushes or similar applicators will melt. Natural fiber brushes can be used, but are more expensive and difficult to find.

### **Inoculation equipment**

Sawdust spawn requires a simple plunger or inoculation tool to pack the right amount into the drilled holes. Dowel spawn plugs are inserted into the logs and usually hammered flush with or just below the surface of the log. Both types need to be waxed.

### **Labels for the logs**

Purchased or handmade labels from aluminum cans work well. It is important to label each log with the date it was inoculated, the tree species, and the type of spawn used.

## **Growing Process**

### **Obtain logs**

Cut or obtain fresh-cut logs during the dormant season when sap is running in the tree and contains the maximum amount of stored carbohydrates—either in the late fall when sap is moving down into the roots, or in the late winter/early spring when it begins to move up to the crown again, roughly Thanksgiving to St. Patrick's Day. During log cutting, it is important to minimize damage to the bark layer.

## Inoculate logs

Inoculate the logs by drilling a pattern of holes through the bark and into the sapwood. Drilling adjacent rows offset from the next row makes the classic diamond pattern. Holes within rows need to be six inches apart. The depth of the drill holes depends on the type of spawn and the inoculation tool used. Fill each hole with spawn, seal the inoculation site, and label the log. A rule of thumb is that the number of rows down the length of a log should be one less than the number of inches in diameter at the log's small end. For example, if the log is five inches in diameter, there should be four rows of holes down the log's length. Inoculation should occur within two weeks of felling a tree.

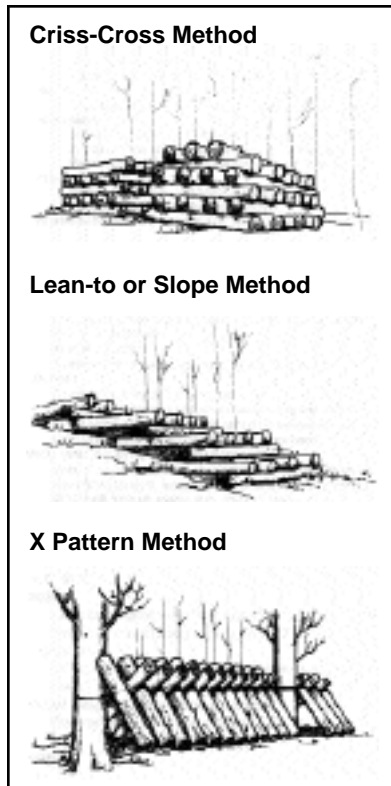


Figure 1: Common stacking methods.

## Incubate logs

Incubate the logs until the mycelia of the mushroom (the "root" system of the fungus and really the major body of the organism - mushrooms are simply fruiting bodies of the organism) has had the opportunity to colonize the whole log, a process called the "spawn run." Depending on the strain of spawn used, the specific local conditions, and the care with which moisture content is monitored, the spawn run may take from six to eighteen months, after which the first "fruiting" will occur. During this time, the logs should be in a "laying yard" where they are heavily shaded (75 to 80 percent shade), and where there is a source of water nearby. Logs are often stacked "lean-to" style (one log flat on the ground with three or four logs resting one end against it, and the pattern repeated). This keeps them close to the ground where they can absorb moisture. See Figure 1 for other methods. Some mushrooms (i.e., maitake) produce most effectively when one end of the log is buried in the soil, or when the log length is half-buried in soil, although this stacking style may create a climate for greater contamination of the logs by other fungal and bacterial species. The grower needs to determine the right balance for moisture retention and air circulation when deciding which stacking method to use. The optimum situation is when the bark remains dry to prevent contamination while the inside remains moist.

## Monitor moisture content

This should be done on a bi-weekly (summer) or monthly (winter) basis. If the logs dry out, the fungus will die. There are some basic formulae for calculating the appropriate range of percent moisture in the logs based on weight. Simply put, cut a one-inch wide section ("cookie") out at six inches from one end of a log. Weigh the section and the larger end of the log immediately. Dry the cookie overnight in the oven (300 degrees F) and re-weigh. The dry weight of the large log piece can then be calculated from the ratio between the fresh and dry weights of the cookie. The range of weights (fresh to dry of the log section) is what indicates whether or not the logs need watering. The section of the "moisture content" log should be weighed regularly. It is wise to have a moisture content log for every ten or fifteen logs in a pile. If the moisture content logs weigh lower than the midpoint of their range, all logs should be soaked or sprinkled with water equal to one inch of rainfall over a 24 hour period.

## Harvesting

Once the spawn run is complete (white mycelia usually show at the ends of the logs) and the weather conditions are favorable (warm and moist - often when the seasons change), the fungi will begin to fruit. If controlled production is desired, the logs can be immersed in water for 24 hours, which will force the logs to fruit about a week later. The flush lasts

about a week and the producing logs then need to rest eight to twelve weeks before another soaking. Logs can produce about 10 percent of the wet weight of the original log in mushroom rooms over their productive lifetime. If the logs fruit at will, they will produce over a longer period of time, and if they are forced, the same total production will occur in a shorter time. Once logs begin to fruit, they will normally produce mushrooms one to several times a year for up to six years.

Mushrooms should be harvested on a daily basis, usually in the afternoon when they are dry. Mushrooms are removed from the log by twisting or cutting at the base when they have opened about 60 to 75 percent. They should immediately be put into cardboard boxes and refrigerated. Refrigeration can extend the shelf life of mushrooms from four to five days to up to two or three weeks. Mushrooms of lower quality or freshness can be dried. Mushrooms can be dried by placing them over dry, warm air, preferably in sunlight which increases vitamin D content. Seven pounds of fresh shiitake mushrooms yields about one pound dried.

### **Marketing**

Be sure to find a market before growing mushrooms although marketing should also take place both during and after growing the mushrooms. Restaurants, farmers' markets, supermarkets, health and natural food stores, and harvest festivals are all good options for marketing exotic mushrooms. When marketing to supermarkets, it is important to arrange for a food tasting demonstration in the market so that consumers can sample the flavor of the mushrooms. Clientele for natural food markets and farmers' markets are more likely to try something new and different, even without first tasting it. Shiitake mushrooms are easily dried and reconstitute well, so marketing by mail is also possible.

### **How many logs?**

A ten-log operation is typical if mushrooms are to be grown for personal use or for family and neighbors. To produce commercially, 200 to 500 logs is a good beginning size, and to produce as a full-time business, thousands of logs are necessary. Management and monitoring are largely labor, rather than equipment, costs. A couple or a family can manage a less-than-500 log farm. When there are thousands of logs involved, hired labor probably will be necessary, especially for cutting logs and inoculating them.

### **Additional Information**

- Eagle Bluffs Environmental Education Center (contact Joe Deden), (formerly Forest Resource Center), 1991 Brightsdale Road, Route 2, Box 156A, Lanesboro, MN 55949. Phone: 507-467-2437
- Fungi Perfecti (contact Paul Stamets), P.O. Box 7634, Olympia, WA 98507. Phone: 206-426-9292
- Northwest Mycological Consultants (contact John Donoghue), 702 NW 4th Street, Corvallis, OR 97330. Phone: 503-753-8198
- Field & Forest Products (contact Joe Krawczyk or Mary Ellen Kozak), N3296 Kozuzek Road, Peshtigo, WI 54157. Phone: 715-582-4997
- Mushroompeople (contact Frank Michael), P.O. Box 220, Summertown, TN 38483. Phone: 931-964-2200
- Mushroom Harvest (contact George Vaughn), P.O. Box 5727, Athens, OH 45701. Phone: 614-448-6105
- "Growing Shiitake Mushrooms." Oklahoma Cooperative Extension Service Publication F-5029.

#### **Author**

Dr. Deborah B. Hill, Professor, Department of Forestry, University of Kentucky, Lexington, KY 40546-0073

---

For more information contact the USDA National Agroforestry Center (NAC), East Campus-UNL, Lincoln, Nebraska 68583-0822. Phone: 402-437-5178; fax: 402-437-5712.

The National Agroforestry Center is a partnership of the USDA Forest Service, Research & Development (Rocky Mountain Research Station) and State & Private Forestry and the USDA Natural Resources Conservation Service. The Center's purpose is to accelerate the development and application of agroforestry technologies to attain more economically, environmentally, and socially sustainable land-use systems. To accomplish its mission, the Center interacts with a national network of cooperators to conduct research, develop technologies and tools, establish demonstrations, and provide useful information to natural resource professionals.

---

The United States Department of Agriculture (USDA) prohibits discrimination in its programs on the basis of race, color, national origin, sex, religion, age, disability, political beliefs and marital or familial status. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (braille, large print, audiotope, etc.) should contact the USDA office of Communications at 202-720-5881 (voice) or 202-720-7808 (TDD).

To file a complaint, write the Secretary of Agriculture, U.S. Department of Agriculture, Washington, D.C. 20250, or call 202-720-7327 (voice) or 202-720-1127 (TDD). USDA is an Equal Employment Opportunity employer.