ALABAMA COOPERATIVE EXTENSION SYSTEM

Shiitake Mushroom Production on Logs

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UNP-25 Shiitake Mushroom Production on Logs

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Introduction

Unlike white button mushrooms, shiitake mushrooms grow on live hardwood substrate. The hardwood can be in the form of logs or sawdust. Shiitake mushrooms prefer species such as oaks, hornbeam, and hard maples but will produce on several other wood species. Hardwood logs about 3 to 6 inches in diameter and 30 to 48 inches in length are inoculated with the fungus in a stage of its life cycle called mycelium. The spawn is placed into the logs 3/8 to 1 inch deep. Each log can grow mushrooms up to 3 years depending on log diameter, hardness of the wood, contamination, and growing environment. The logs must be maintained in an environment above 40 percent moisture and kept fully shaded in the summer. Under natural conditions, shiitake mushrooms fruit in the spring and fall when temperatures are cool.

Seventy-five percent of the forestland in Alabama belongs to small, private owners. Used almost entirely for timber cutting, the land produces about half its potential. Because pines have been removed at a higher rate than hardwood species, the economic use for hardwoods is considered limited. Hardwood sold as firewood brings about $150 per cord while that same cord of wood (about 240 logs), used to grow shiitake mushrooms, could gross $2,000 to $3,000 during the 3 years that mushrooms can be harvested.

Hardwood trees removed from timberland during thinning operations can be used to grow shiitake mushrooms. In addition, when the saw timber is finally harvested, large hardwood limbs are also useful for growing the mushrooms. Successful shiitake cultivation is not difficult; however, it is hard to control and improve a process that has evolved in nature.

Chapter 1:
Preparing Logs for Inoculation

Selecting the Wood Species

Tree species selected for shiitake cultivation influence the overall yield of mushrooms and the likelihood of contamination. Oaks and members of the oak family, especially red and white oaks, are the best species for shiitake cultivation. However, recent research also includes yellow poplar (*Liriodendron tulipifera*), ironwood (*Ostrya virginiana*), American hornbeam (*Carpinus caroliniana*), sweetgum (*Liquidambar styraciflua*), northern red maple (*Acer rubrum*), and paper birch (*Betula papyrifera*). White and red oaks, American hornbeam, hard maples, and sweetgum are probably the most productive species. Availability of tree species will vary with location. In southern climates, avoid soft hardwoods such as aspen and willow because of the increased likelihood of contamination problems and low yields. Conifers such as pine, spruce, fir, and larch should not be used in any climate.

The site on which trees grow can influence the nutrient content of logs. The best shiitake logs come from trees grown on fertile sites. The trees selected for shiitake cultivation should be living, healthy, vigorous specimens free from any obvious insect or disease problems when cut. However, the success of a tree species for shiitake production can ultimately be determined only by cultivation of the mushroom on that species in a specific environment or climate.

If you look at the cut end of a log, you can usually see two shades of wood color. The outer portion of the log is bark and cambium (Figure 1). The lighter, inner wood is the sapwood; the darker wood in the center is the heartwood. Shiitake grows best in the sapwood and cambium because they contain the most readily available nutrients and have higher moisture content than the heartwood. Trees with large sapwood areas and small heartwood are preferred for shiitake production not only because of the high nutrient content in the sapwood but also because it is difficult for shiitake to break down heartwood material.

Figure 1. The sapwood and cambium are sources of nutrition for shiitake. The larger the sapwood area, the more productive the log will be.

Felling of Trees

When leaves fall off trees, the sap flows down to the tree roots. In the winter, the sap generally does not flow, and in the spring, the sap rises through the trunk and stems to the leaf buds. During dormancy, the sapwood contains high sugar levels and the bark is tighter. Therefore, trees should be felled during the dormant season. This is the period from about half color change in the canopy in the fall to before bud swell in the spring.

Trees should be cut about 2 weeks before the intended time for inoculation. If inoculated sooner, the trees' natural chemical defenses against invasion may still be active and could prevent the shiitake fungus from growing.

Cutting Wood to Size

Avoid damaging the bark because it creates an opportunity for other invading fungi to enter. Just before inoculation, the trees can be cut into suitable lengths for logs. Log lengths can vary from 3 to 4 feet, and the diameters can range from 2-1/2 to 10 inches. Logs that are 40 inches long and between 2-1/2 and 5 inches in diameter are easy to handle and are the most productive.

In dry climates with less than 40 inches of precipitation per year, logs cultivated outdoors ideally should be in the 4- to 6-inch diameter class. Smaller logs dry down rapidly resulting in poor spawn run. In most climates, however, some type of moisture supplementation is required for logs during spawn run and before fruiting.

Chapter 2:
Inoculation

Equipment

Proper tools and equipment can make inoculation fast and easy. For any operation, a high-speed drill, inoculation tool, wax baster, and a stove to heat the wax are essential (Figure 2).

Inoculation

Inoculation is the introduction of the live fungus into the log. This live fungus is mixed with sawdust, grains, and other nutrients or is grown on a wooden dowel. This mixture, called spawn, is the mycelium of fungi growing on a substrate and prepared for propagation of mushrooms. Mycelium is a network of hyphae or the vegetative portion of a fungus. The mycelium runs through the log or substrate like the roots of a plant run through soil.

Figure 2. Having the right tools to inoculate shiitake mushrooms will make the job much easier and faster. It would cost $500 to purchase the tools shown in this picture.

Logs should be inoculated only if the daytime temperatures are consistently above 50 degrees F. In warm climates, it may be possible to inoculate October through mid-December and to begin again in February.

Logs are sometimes too dry to inoculate. Logs with moisture content of less than 40 percent should be soaked for 1 to 3 days or until the desired moisture level is reached. Methods of determining moisture in logs are explained in Chapter 5. The logs must be inoculated right after soaking and then immediately stacked in a laying yard or house.

To inoculate, drill holes into a log and then fill with spawn. Drill a 5/16-inch diameter hole 1 inch deep for dowel spawn and a 7/16-inch diameter hole 1 inch deep for sawdust spawn. A high-speed 1/2-inch or 3/4-inch, 8,000 rpm drill works best to drill a large number of logs (Figure 2). However, a lower priced alternative is an angle grinder with a high-speed drill bit adaptor (Figure 3). The angle grinder may be slower to use because two hands are generally needed to hold the grinder, and you cannot rotate the log as holes are drilled. For rapid colonization of the log, the following drilling pattern is used:

Figure 3. Convert an angle grinder into a high-speed drill with this specialized adaptor. It fits on a 5/8-11 spindle. This adaptor works only with high-speed drill bits.

Starting 2 inches from the butt end, drill the first hole in the row (Figure 4). Drill the second hole 5 to 8 inches from the first and so on down the length of the log until the other butt end is reached. Place the next row of holes 2 to 4 inches below or above the first row and stagger the holes between the holes in the first row. Continue this pattern around the whole log. Avoid letting soil or debris contaminate the inoculation holes. Inoculation rates, or the number of holes drilled, can be increased for quicker colonization, but this will also increase the amount of labor and cost per log for spawn. Rates of 30 inoculation sites per 10 pounds of log significantly increase yields over 5 or 10 holes per 10 pounds of log.

Figure 4. Drill logs from one end, spacing holes in the row about 5-8 inches apart. Roll log and stagger the next set of holes about 2-4 inches below or above the first set. Continue drilling around the entire log.

After the holes are drilled, the log should be inoculated as soon as possible to prevent drying and contamination. To inoculate with dowel spawn, place a dowel over the hole and tap it into place with a hammer. Poke a thumb inoculator into a container with spawn to fill the tube. When it is full, hold the inoculation tool over the drilled hole and press the thumb plunger. This will fill the hole with spawn to the bark level. If spawn protrudes above the bark, either press it into the hole or wipe off the excess.

Sealing the Inoculation

When the holes are filled with spawn, seal with hot wax as soon as possible to prevent drying and contamination. Several kinds of wax can be used. Paraffin is commonly mixed with up to 20 percent mineral oil, by volume, to improve the flexibility of the seal. Cheese wax is softer and more pliable so it does not require additional mineral oil. Beeswax can be used, but it often attracts bees when heated.

To apply, heat the wax until it smokes (about 260 degrees F) and with a wax baster (metal turkey baster), apply just enough to cover the spawn and seal the hole. The wax will bubble slightly and dry in a thin, clear layer. This may kill the spawn on the surface of the hole, but most of the spawn will be unaffected because the wax cools rapidly. The hot wax will also surface pasteurize the inoculation site and reduce the potential for contamination. The ends of the logs can be dipped in the wax pot or brushed with heated wax (Figure 5). Some producers prefer not to wax the ends of the logs because they feel water absorption is slowed during soaking. On the other hand, in hot, dry climates, excessive moisture can be lost from unsealed log ends. Hot wax can injure people and damage property so keep a fire extinguisher available as well as small chunks of wax to place in the pot to cool down the wax.

Figure 5. The ends of the logs should be dipped in hot wax or brushed with wax, in southern climates, to reduce moisture loss and contamination.

Labeling the Logs

Label logs with the inoculation date and strain of spawn used. Strains fruit at different temperatures so labeling the logs lets you know when to soak each strain. Use various colors of spray paint to indicate soaking "seasons" or temperatures. Be sure you keep a list of which colors are used for each strain or groups of strains. For example, blue paint can be used for strains that fruit when the log temperature is between 52 and 56 degrees F. When the average daily temperature reaches 50 degrees F in the spring and 58 degrees F in the fall, these blue-edged logs should be soaked in preparation for fruiting.

Spawn Growth

Sawdust spawn, when placed in the log, generally has higher moisture content than the log. This causes the moisture to move away from the spawn into the log. If too much moisture is lost, the spawn will dry out and die, therefore, it is important to provide a cool, moist environment for newly inoculated logs and to provide supplemental moisture if logs begin to dry. To reduce spawn moisture loss and log drying, apply a good seal over the inoculated spawn and bulk-stack the logs for a month or two. Logs left outdoors can be covered with burlap or other porous materials that will allow moisture to enter and reduce drying. Be sure to monitor inoculation sites for green *Trichoderma* growth (Figure 6). If *Trichoderma* appears, increase log ventilation and/or reduce the humidity around the logs.

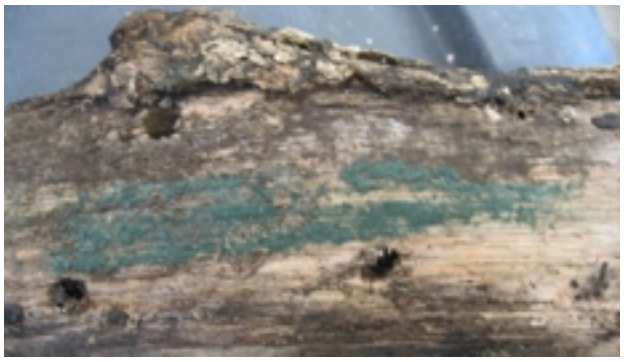

Figure 6. *Trichoderma* is an invasive green fungi that can reduce yields of mushrooms by competing for nutrients and space in the substrate.

After inoculation, observe the growth of the spawn every 30 days. The spawn can usually be seen growing right through the wax by the change in color. At first, the color is light; then it becomes pure white. This may take a while in winter, but in spring, this may only take 1 to 2 weeks.

Mycelium Run

Spawn growth appears as white patches around the inoculation site and the ends of the logs. This means the mycelium in the spawn mixture has recovered from the inoculation process and resumed growth. When this recovery occurs, the mycelium will grow through the substrate like plant roots through soil. During mycelium run, the log environment must be managed by controlling moisture and air circulation. In the winter months, there is generally enough rain to stabilize moisture. But moisture may need to be applied by irrigation in a dry year.

Under good growing conditions, mycelia often appear at the end of the logs. It appears white in a pattern related to the inoculation sites closest to the end of the log (Figure 7). It may later turn dark brown or black. When a log is colonized, it does not have to be inoculated again.

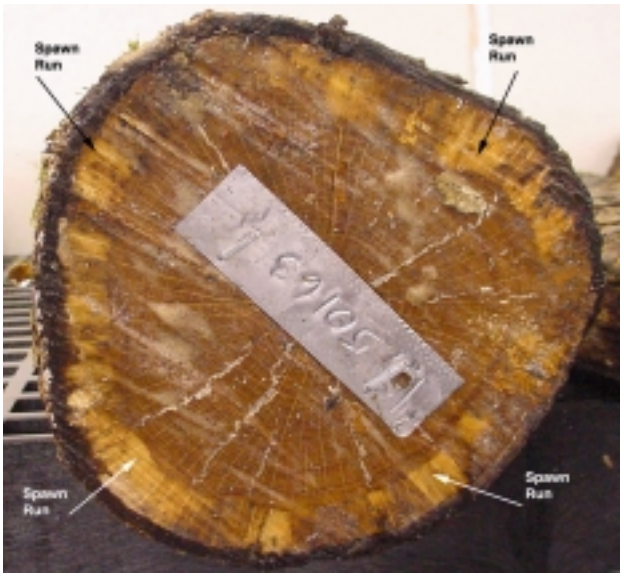

Figure 7. Mycelia will appear at the end of the logs when it begins to run. The white pattern often reflects the inoculation hole pattern at the end of the log.

Chapter 3:
Spawn Ordering, Storage, and Handling

Spawn Production

Shiitake reproduce in nature by spores produced by the mushroom and spread to other logs. However, in cultivation, reproduction by spores is unreliable. Instead, logs are inoculated with actively growing shiitake fungus. These active fungal cultures used as inoculum for mushroom cultivation are called spawn. The spawn is usually purchased from shiitake spawn dealers. A pure strain of mycelium is taken from a culture tube and multiplied. It is then transferred to sterilized grain and eventually to sawdust medium.

Shiitake mycelia digest lignin and cellulose, which are major constituents of wood. Shiitake is commercially cultivated on two different substrates – hardwood logs or particulate materials (ground corn cobs, cotton seed hulls, chopped wheat straw) usually including hardwood sawdust. Shiitake spawn is available in two forms, sawdust or dowel. Sawdust spawn is hardwood sawdust often supplemented with wheat bran, grain, or other plant derivatives and colonized by the shiitake fungus or mycelium. Dowel spawn is made from hardwood dowels that have been colonized by the shiitake fungus. Generally, grain spawn is used to inoculate sawdust blocks for production of shiitake. Spawn is incubated in a growing room before shipment to growers or used as a fruiting substrate. Healthy, actively growing shiitake spawn is moist, white, and fuzzy (Figure 8). The spawn should have white mycelium running throughout the spawn block. If you refrigerate your spawn before inoculation or if the mycelium is not apparent throughout the block, bring it to room temperature for at least 2 to 3 days prior to inoculation.

Strains

Shiitake strain selection depends on the production environment, the wood type inoculated, and the general characteristics of the strain. To extend the harvest season, it is generally best if more than one strain is used in production.

Figure 8. Shiitake spawn should be white and fuzzy throughout the bag. If large brown areas of sawdust are visible, keep the bag at room temperature until all sawdust is white. Only completely white spawn should be used for inoculation.

Common strain characteristics are as follows:

- Time from inoculation to fruiting: Varies from 6 months to 2 years
- Temperature requirements for fruiting: Ranges from 41 to 86 degrees F
- Type of fruiting body: Size and shape of caps can be small and flat to large and rounded
- Color of cap: Tawny to dark brown
- Moisture requirements: Vary

For cold weather strains, time from inoculation to fruiting ranges from 6 to 18 months. Natural production is usually early to mid spring and late fall, when temperatures are between 55 and 65 degrees F during the day and 40-plus degrees F at night. On the other hand, warm-weather strains will fruit when temperatures are between 50 and 82 degrees F. First fruiting occurs between 6 and 14 months for most strains. The natural fruiting season is mid spring through mid fall depending on the summer temperatures. Wide range fruiting strains will fruit between 50 and 80 degrees F. They generally fruit between mid-spring and mid-fall, 6 months after inoculation.

Inoculate logs that will be placed in an indoor environment with several strains. When heating and cooling are used in the indoor environment, logs still respond to temperature and seasonal changes. This would typically occur when changing from cooling to heating in the fall and heating to cooling in late spring and summer. When outdoor temperatures are the same as fruiting temperatures, fans must be used to circulate air inside the fruiting room. Fans will dry out logs and mushrooms, so compensate moisture loss by increasing humidity with humidifiers or mist systems. Do not spray water directly on the logs or the mushrooms.

Ordering Spawn

When ordering spawn, check the volume or weight of spawn or the number of logs a bag of spawn will inoculate. The cost of spawn varies greatly among vendors. Generally, the cost should be about $1.00 or less per average size log. A 5-pound bag of spawn should inoculate about 14 20-pound logs or about 291 pounds of logs. Spawn more expensive than this may be overpriced. If you are buying 10 or more bags of spawn, ask for a volume discount. Prevent weed fungi and contaminants from affecting the shiitake spawn by not opening the spawn container until you are ready to use the contents. Keep spawn in dark storage and refrigerated at 34 to 40 degrees F. Do not freeze. Grain or sawdust spawn may be kept in cold storage for 1 to 3 months. An excessive accumulation of brownish liquid in the bottom of the spawn bag indicates deterioration of quality. Don't use it for inoculation. Store spawn at about 70 degrees F to encourage active fungal growth 3 to 10 days before inoculation, depending on the growth quality of the mycelium.

Chapter 4:
The Laying Yard

The laying yard is where inoculated logs are stored while the spawn runs. This may be inside or outside. How logs are stacked and the environmental requirements are similar for both. Therefore, the term "laying yard" can refer to an outdoor or an indoor location.

Location of Laying Yard

The topography, altitude, latitude, and amount of shade affect how easily logs become contaminated. The initial yard should be a location not previously used for cultivating shiitake and should be well away from areas previously used in cultivation. Like crops in a field, contaminants and pests will build up in an area if continuously used for the same crop. If using adjacent areas each year, then the direction of each new stack should be upwind from the previous year. The maturing yard can be the same area used from year to year.

If an area warms up rapidly after a rain and becomes too humid, it is more susceptible to contamination. If the yard is located where it receives a breeze after rain, the logs there will dry easily and be less likely to be contaminated.

The radiant heat from the sun creates heat in the logs and stimulates the growth of the spawn in the colder months. If the sunshine is too strong, it will raise the temperature too high inside the log and kill the spawn. The lack of heat from the sun can result in too much humidity, which is not desirable. For this reason, air movement is very important. If a log is inoculated in fall or winter, leave it unshaded during the first winter until April or so. After this time, shade is required until fall. The shade can best be provided by different conifer trees or by shade cloth. About 80 percent shade is generally ideal in the South.

Shade provided by a tree canopy is different depending on the type of tree, the size of the tree, and how dense the forest is. Generally, pine, cedar, and deciduous trees (not as good because of contamination) are used. The shade of oak trees is much denser than that of conifers so the spawn growth slows down on logs in their shade compared to logs stacked under conifers.

The type of conifer is also important. A pine forest is ideal because it allows good sun exposure and is drier than most other conifers because of the air movement. However, if a forest is too thin, too much sunlight in summer can be a problem. Pine forests previously were considered less than ideal, but research has shown them giving the best results.

If artificial shade must be used, consider the percentage of shade it will provide, the air movement even when raining, economy, and weight. Plastic shade cloth is generally considered best because it is lightweight, durable, and inexpensive. It also provides the proper shade and allows good air movement. The shade cloth can be suspended 6 inches over the logs or about 7 feet off the ground. Plastic or nylon line is better than wire for suspending the cloth. Elevated shade is more costly and requires more support but is easier to work under. The shade covering can be overlaid with plastic to extend the fruiting season of some of the logs. In spring and fall, when

Figure 9. Logs covered with burlap will hold moisture longer than logs in the open air. However, the increased moisture can promote rapid contamination.

changing temperatures and increased rains cause natural fruiting, some of the logs can be protected from the rain and fruited later to extend the harvest season. Place burlap over the logs to provide shade and hold moisture (Figure 9). Remember that burlap can also reduce airflow and increase contamination.

Stacking the Logs

You can see the effects of temperature in winter and summer by observing the fruiting of different logs taken from a crib stack of colonized logs. The logs on top and the outside will be warmer in winter and, if soaked, will produce more mushrooms than the logs from the interior of the stack. In summer, the interior and lower logs will be cooler and, therefore, will produce more mushrooms when soaked.

Logs stacked in winter should be stacked far apart and placed where they will receive a maximum of sunlight to warm them up. Conversely, in summer, logs should be stacked in a shady area, more vertically and closer together, in order to reduce the temperatures. If logs are too close and have too much shade, the higher humidity may cause contaminants to flourish.

Several stacking methods have been used:

- A-frame stack
- Lean-to stack
- Triangle
- Crib stack

A-frame stack: A good method because the rain will hit all along the length of the log. Be careful not to make the horizontal support too high as this will make the stack too upright. A 45- to 60-degree angle to the ground is best (Figure 10).

Lean-to stack: This method provides the best exposure to sun and rain. Be sure the stack is at a 45- to 60-degree angle with the ground, and keep the number of logs in a row small. In this method, it is best to stack downhill when stacking on

Figure 10. In the A-frame stack, logs are at a 45 to 60 degree angle to the ground. Water will run off rapidly and it is easy to monitor logs.

hillsides to provide maximum exposure to the sun and rain while the logs lay almost horizontally (Figure 11).

Crib stack: This allows a large number of logs to be stacked in a small area, but the stack contains different microclimates and results are uneven. The more logs in a stack, the worse the results are. This method should only be used for incubating logs to provide high-moisture conditions (Figure 12).

Triangle: Logs are stacked to form a triangle on the ground and then cross-stacked to increase light exposure. This method provides more sunlight and air than the crib stack method and it is more successful (Figure 13).

Firewood stack: If this stacking method is used to conserve space, separate logs with a small piece of lattice wood or shims to keep them from touching (Figure 14). If logs touch for any period of time, the mycelium will grow from log to log and when they are moved, the bark will come off of one of the logs. Stacking logs this way will keep the inner logs cooler and moister, but may encourage *Trichoderma* (see glossary). Small shims, separating logs, may provide sufficient aeration for drying inner logs. Don't stack logs this way in winter if left outdoors; logs will stay too cool and mycelium growth will be slow.

Figure 11. [Below] The lean-to-stack provides the best exposure to sun and rain. If more than three logs are used per row it will be more difficult to spot log problems. However, fewer logs per row require more space.

Figure 12. This crib stack method accommodates many logs in a small space. This stacking method is unsuitable for fruiting, since access to the logs is limited.

Figure 14. Logs should rarely be stacked like firewood. Interior logs will not be ventilated nor will they receive much moisture. Once the mycelium begins to run, any logs touching will knit together and when the logs are moved, bark will be pulled off adjoining logs.

Figure 13. In the triangle stack, logs are stacked to form a triangle on the ground and then cross-stacked to increase exposure. This method provides more sunlight and air than the crib stack method.

Management of the Laying Area

During the spring, light is increasing in intensity, trees are budding, and rains usually come. The temperature is increasing, often accompanied by more wind. The inoculated logs begin to lose their vitality and contamination rates begin to climb. This is the most important time to work on creating the proper conditions in the laying yard.

Many books suggest that logs be turned every month or every 3 months, but tests have shown this practice to be unnecessary. In fact, the opposite may be true. Contaminants may begin on one end and then spread more rapidly when the logs are turned. The shiitake mycelium forms a fungistatic barrier against the other organisms in the log. If the log is turned, the contaminants begin to grow because the log dries out at the top, and the shiitake mycelium slows down.

Success or failure is usually determined during the time from spawning until the end of the first summer. This is the most critical period in the cultivation process. Pay careful attention to the conditions at that time. Spawn strains that grow slowly require more care.

Growers must choose a location and stacking arrangement that favors fungal growth. Ideally, all logs should have equal access to rainfall and enough air circulation to allow log surfaces to dry out between rainfalls or sprinklings. Optimal conditions for shiitake growth are temperatures of 60 to 75 degrees F with a relative humidity of 80 to 85 percent. Experiment to find out which laying position works best for your site.

Factors that influence log moisture content and retention are as follows:

- Log species and diameter: Thick-barked species such as oak absorb water through the bark better than thin-barked species such as birch or cherry. Thin-barked species take water better through butt ends.
- Amount and duration of shade: Evergreens provide shade year round.
- Amount and duration of rainfall and relative humidity.
- Strength and duration of wind.
- Slope of the laying yard (southern exposure versus northern exposure)
- Position on the slope (windy ridge top versus cool damp valley)
- Surrounding vegetation

Chapter 5:
Log Moisture

Measurement

If during inoculation, logs are found that are very dry then they should be soaked for at least 24 hours before inoculation. After inoculation, it is also important to maintain the moisture content of the logs. To determine initial moisture content, use the following formula and procedure:

[(wet weight – dry weight)/wet weight]
X 100 = percent moisture

Select a representative log and cut, from the center, a disk about 3/4-inch thick. Do not cut from the butt end because this may give a low reading. Weigh the disk on a kitchen scale. This is the wet weight. Place the disk in an oven overnight with the temperature set at 200 degrees F. Leave the oven door slightly ajar to allow moisture to escape. Weigh the disk in the morning. Place it in the oven for another hour and then reweigh. If the disk has not lost any more weight, this is the dry weight. Place the appropriate numbers into the equation to determine log moisture content. If the moisture content is below 35 percent, the logs should be soaked to increase the moisture to 40 percent or more before pinning (just before fruiting).

Moisture Management

To manage log moisture, reference logs should be selected and weighed regularly. Choose a log from each wood species and size category. For example, if you have white oak and sweetgum in diameters ranging from 4 to 8 inches, select one 4-inch log, one 6-inch log, and one 8-inch log from each tree species (a total of 6 logs). Weigh each log immediately after inoculation and record the weights. Mark the logs with special tags or brightly colored paint. Weigh these reference logs regularly. To determine moisture loss, subtract current weight from the initial log weight. Divide this difference by the initial log weight and multiply by 100.

[(original log weight – current log weight)/ original log weight] X 100 = Percent moisture loss

If the amount of weight loss (moisture loss) exceeds 10 percent of the log weight, all logs of that species and size should be soaked. Moisture management is one key to successful shiitake production.

As the logs decay, they become lighter. Every 6 months, calculate a new "original" log weight by obtaining the weight of the reference logs after they have been thoroughly soaked and the excess moisture is allowed to drain. This "new original" weight should be less than the log's original weight and should replace it in the above equation.

Log moisture content should be checked periodically throughout the growing season. Moisture content must be above 35 percent and preferably above 40 percent. If the moisture content falls below 35 percent, soak and sprinkle the logs until the moisture content is increased to 35 percent or more. Any water is satisfactory as long as it is free of suspended solids and organic matter. Chlorinated water from city or county treatment plants is suitable. Using a 150-gallon

tank, about 30 logs require 30 gallons of water for soaking. The spent water should not be reused for soaking, as it may spread contaminants among logs, however, the water can be used for gardening or other crop production.

If a water source is not available, a water catchment can be constructed. A 10-foot x 12-foot structure, with roof overhang, has about 143 square feet of surface area for collection (Figure 15). A one-inch rain will result in 89 gallons of stored water. The cost of the structure shown was $1,200. The most expensive inputs were the collection containers ($300) and the roofing panels ($269). Less expensive materials and scrap wood can be used to reduce the cost of construction.

If large amounts of water are applied through an overhead irrigation system, do not allow the water to run for more than 8 hours at a time. Extended overhead watering will cause water to accumulate under the bark, which will cause it to fall off prematurely.

Allow 24 hours between irrigation applications. A fine spray or fog will increase humidity and log moisture without causing excessive surface moisture accumulation on the logs. However, all irrigation systems should be turned off at night because abundant moisture is generally in the air. Provide ventilation when humidity levels are high.

When logs start to dry, they are losing vitality and are susceptible to contamination. Watering, unless done carefully, may increase the growth of contaminants. If conditions are not windy, watering must be done carefully so the outsides of the logs do not stay wet for long periods. Brief, light watering may favor contaminants on the logs' surfaces without actually raising the moisture content of the logs' interior.

Figure 15. A water catchment can provide enough water to soak 90 logs with just one inch of rain. The surface area of this catchment is about 143 square feet and it will collect 89 gallons of water from one-inch of rain.

Chapter 6: Production

Shiitake production is very labor intensive and often begins as a family affair and ends when children go off to school. Plan for labor-intensive periods such as tree felling, inoculation, soaking, and harvest periods. Remember that logs are heavy, especially after being soaked, and that you should accommodate lifting with back support, forklifts, or other aids.

The most profitable log operations fruit their logs year-round and are reliable weekly product sources for buyers. Unfortunately, outdoor production alone does not accommodate year-round production. By inoculating outdoor logs with various seasonal strains, production can often be extended and you may be able to force fruit logs up to four times per year. Forced fruiting is accomplished by creating conditions that stimulate fruiting. If the spawn strain is a cold-weather strain, you may be able to fruit logs in December or January by soaking them in warm water. You will be able to fruit them again in March or April and again in October. It will be difficult to force cold-weather strains in the summer; therefore, you should have a selection of wide-range and warm-weather strains for summer fruiting. These strains will naturally fruit in April and October. They can be forced to fruit in June or July if allowed to get slightly dry and then soaked in cold water.

To determine if it is time to fruit the logs, first check for spawn run. If the inoculation sites are white and the log ends have white v-shapes at the end, the logs are probably ready to fruit. If logs are grown in forest or outdoor conditions, they will fruit naturally when the weather and moisture change in the spring and fall. Logs fruited indoors but left outdoors during spawn run, should be brought indoors and soaked when sufficient logs are showing significant spawn run. Logs kept indoors all season should be soaked on a 12-week schedule, once spawn run is completed. To increase the yields, be sure logs are maintained as suggested below.

In most cases, logs are soaked to force fruiting. Soaking helps concentrate production and increases yields. The soaking time depends on the dryness of the logs. After logs are placed in the soak tank, water replaces air in the logs and forces bubbles to the surface of the tank. Remove logs before bubbles quit forming. Typically, 12 to 72 hours is the range. However, denser wood species such as oak, large logs, and young logs require longer, while older logs and wood species such as sweetgum require less time in the tank.

Soak tanks should have drains at the bottom. A source of hot water is desirable for force fruiting in the winter. Tanks should have a lid or some other means to hold the logs under water; otherwise, logs will float and not absorb sufficient moisture to produce marketable mushrooms. Soaking logs and removing them from the tanks is one of the most difficult activities in log production, but it is also one of the easiest to mechanize. Tanks can be buried in the ground and lifts or tractors used to lower racks into the tank and remove them.

After logs are removed from the tanks and placed in a fruiting area, the logs will begin to dry, which initiates the pinning phase of fruiting. Pinning is the primordium formation or the begin-

Figure 16. Pinning or primordium formation occurs two to four days after soaking. Once pins start to form, logs and pins should be kept dry and temperatures should be at least 60 to 65 degrees F.

ning of mushroom development (Figure 16). During summer months, logs, once removed from soaking tanks, can be placed in front of fans that will help dry the surface and cool the log. Fans should be removed at the first sign of pinning.

Forest-Grown Mushrooms

Many risks are associated with growing shiitake mushrooms outdoors. These include weather conditions, pests (including wild animals), theft, moisture loss, seasonal fruiting, and quality control. Once logs are placed in the laying yard, production management includes the following:

- Maintaining burlap or log covers and checking to be sure they have not blown off or been removed
- Checking moisture of logs. Weighing logs to determine moisture loss. Checking logs for contaminants and to determine if logs are staying too wet.
- Looking for deer, slugs, and other animals that might steal the spawn or later eat the mushrooms.
- Watching for spawn run at inoculation sites and log ends to determine mycelium growth progress in the logs.
- Forcing logs to fruit in the summer by soaking logs in cold (50 to 60 degrees F) water. Forcing logs to fruit in winter using warm-weather strains, warm logs by increasing exposure to sun for 2 weeks. Covering with clear plastic may also warm logs. Once logs are warmed, soak in water that is cooler than the logs. If you can warm logs to 60 degrees F, then soak in 50-degree F water. If you use cold-season strains, soak logs in warm water (60-degree F) without warming the logs.
- When mushrooms are fruiting, checking all logs for slugs. Slugs are very destructive and will go from one mushroom to the next making numerous holes. If your logs are free of slugs after soaking, keep them off the ground and surround the fruiting area with a circle of copper sulfate or salt (sodium chloride). When slugs crawl across these chemicals, they will shrivel and die. If the copper sulfate or salt dissolves due to rain or excessive canopy moisture, reapply it.
- Fruiting logs must be checked daily and in summer months, twice a day. Because mushrooms grow rapidly in warm weather, those just forming in the morning may need to be picked by late afternoon.
- Refrigerating mushrooms as soon as possible. Mushrooms grown outdoors in the summer are warm and will deteriorate rapidly.

Forest-Outdoor/Indoor Production

Logs left outdoors for spawn run and recovery between fruiting periods should be maintained and observed as forest-grown mushrooms described above. However, logs that will be brought indoors

should be fruited on a 12- to 15-week schedule. The indoor production facility is described in the next section.

Divide logs by strain. Determine the best fruiting time for each strain. All logs with strains that can be fruited at the same time should then be divided into 12 to 15 groups, depending on the number of weeks between fruiting. If you have 150 logs inoculated with warm-season strains that you want to fruit in June and you plan to fruit them every 15 weeks, divide 150 by 15. You will then have 15 groups of 10 logs. A different group can be soaked each week for 15 weeks. At the end of 15 weeks, you can begin fruiting the first group again. Keep groups separated by labeling or painting the ends and recording each group's soak date. The following is an example of a soaking and fruiting schedule:

Week One

- Bring 10 logs into the production house. Do not soak during week one.

Week Two

- Soak the logs brought in the previous week; bring in 10 more of the logs in the group.
- After 48 hours, remove the logs from the soak tank.
- Fruiting will begin within 2 or 3 days.
- When logs are no longer fruiting, move them back outdoors.
- Refrigerate mushrooms during the week and sell them when the majority of mushrooms are harvested for the week.

Week Three

- Soak the second set of logs brought into the house and bring in the third set.
- Process as in Week Two.

Continue this process until you have fruited all 15 groups of logs. When all 15 groups have been fruited, you can begin again with group one. This way you ensure yourself a steady production of mushrooms across all 15 weeks.

Indoor Production

Logs left indoors year-round and fruited indoors should be divided into 12 groups. As described for outdoor and indoor production, rotate fruiting for each group but create only 12 groups. When all 12 groups have fruited, begin soaking the first group again. Indoor logs can recover faster than outdoor logs because their environment is controlled to maximize mycelium recovery.

Ideally, the mushroom house should be divided into fruiting and log resting sections. The fruiting section should be cooled or heated as appropriate, have good ventilation to remove excess carbon dioxide and spores, and have a humidity of 85 to 90 percent. The log resting area should be dryer and also be heated in winter or cooled in summer. Maintain indoor temperatures at 70 degrees F during the resting period, reduce to 55 degrees F before soaking, and slowly raise to 65 degrees F to initiate pinning and for fruiting.

Chapter 7:
Harvest

Harvesting

Shiitake mushrooms should be picked when the cap is approximately 50 to 70 percent open. This occurs shortly after the veil between the cap and the stem breaks (Figure 17). At this stage, the gills are exposed but the cap edges are still rolled under the cap. Mushrooms can be harvested by pulling and slightly twisting them off the log. You can also cut them off the log flush to the bark. There should be no pieces of stem left on the growing surface and a minimal amount of wood on the base of the stem.

Generally, the base of the stem is trimmed off with a knife or scissors after harvest, especially if the shiitake mushrooms were grown on a sawdust medium. Shiitake grown on sawdust tend to have longer stems, and sawdust clinging to the base of the stems will fall onto the gills of other mushrooms if not trimmed off. The stem length should not be greater than two-thirds of the diameter of the cap when trimmed. Log-grown shiitake may have shorter stems and might not need to be trimmed. The decision to trim or not is an individual choice to be made by each grower taking into consideration customer preference.

After picking, place the mushrooms in a container designed for maximum ventilation and, therefore, maximum cooling. Numerous plastic mushroom containers that hold 6 to 15 pounds are on the market. The designs of these baskets or boxes allow rapid cooling of the product.

Postharvest Handling

In nature, the role of the mushroom fruit body is to release its spores to complete the mushroom's life cycle. When this task is complete, the fruit body is no longer needed, and it deteriorates very

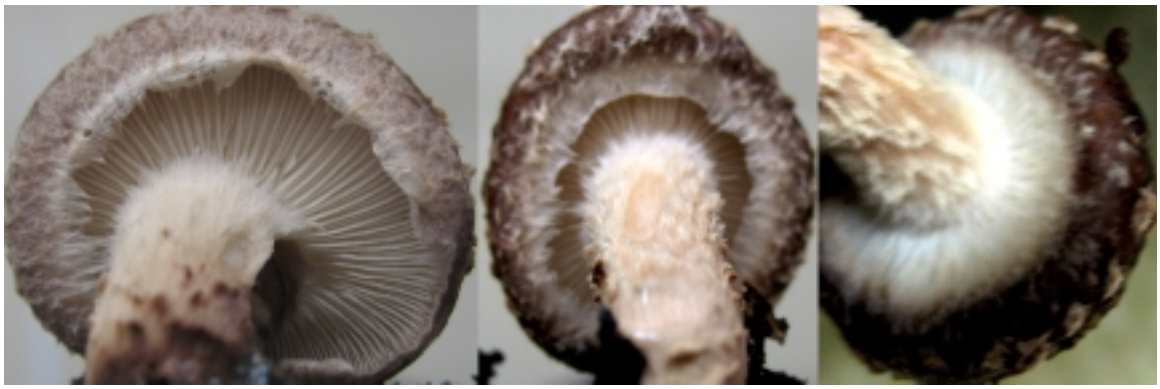

Figure 17. Pick shiitake mushrooms when the cap is 50 to 70 percent open (left) and after the veil has broken away from the stem (center). The mushroom on the right still has the veil attached to the stem.

rapidly. The goal of proper postharvest handling is to slow down this deterioration as much as possible so the consumer gets the best possible quality shiitake.

The first step is accomplished by picking the mushrooms before the gills are totally exposed, all the spores dropped, and the life cycle completed. However, when the mushrooms are picked, they will continue to grow using their stored food reserves in an attempt to complete their life cycle. Picking the mushrooms too early is as bad as picking them too late. Harvesting too early will reduce your total mushroom yields, while harvesting too late will reduce quality, storage life, and value.

Refrigeration

To slow deterioration as much as possible, shiitake should be cooled immediately after picking. The respiration rate may be as much as 3.5 times higher at 50 degrees F than that at 33 degrees F. Therefore, the immediate objective after picking is to cool the product to 33 to 35 degrees F as rapidly as possible. Coolers should have sufficient cooling capacity, high airflow, and high humidity. At no time should any mushrooms be frozen because this will damage the product.

After the initial cooling, maintain the cold, humid airflow. Under ideal conditions, shiitake mushrooms can be kept 1 week and look very good. After the first week, quality deteriorates quickly and as much as 1 percent moisture loss per day can occur.

Drying

Drying can preserve mushrooms for 6 months to a year. Shiitake are usually air dried to a moisture content of about 13 percent and have a 7 to 1 reduction in weight. This means that 7 pounds of shiitake mushrooms dried to 13 percent moisture will yield 1 pound of dried mushrooms.

Before drying, separate mushrooms by size and grade. Remove stems completely, as they harden when they dry. Place mushrooms on trays with gills down. Avoid allowing the mushrooms to touch each other. Mushrooms can be dried in the sun but the quality is usually lower than it is for those dried in a controlled-air dryer. Convection or forced-air dryers can be used for air-drying. Forced-air dryers use fans to move the air. The high temperatures reached during air-drying denature enzymes and kill bacteria. Home food dryers can be used to dry 2 to 3 pounds of fresh mushrooms at a time.

Chapter 8: Marketing

Current Production

Calculations based on recent production statistics show less than 22 percent of the mushrooms grown and sold in the United States are from logs. Most researchers and producers agree that artificial substrate production is quicker, more controlled, and more cost effective than log production. Artificial substrate production also utilizes waste products (sawdust, cottonseed hulls, corn cobs, etc.), is easier on the back (blocks weigh 6 pounds or less), and yields more mushrooms per square foot. However, the medicinal and marketing benefits of log-grown mushrooms should demand a higher price.

Medicinal Value

Lentinan, one of the medicinal components of shiitake mushrooms, has been researched for more than 40 years in Asia. Only during the past 5 to 10 years have U.S. scientists started to evaluate this mushroom with regard to its cancer fighting properties, ability to lower cholesterol and blood pressure, and numerous other properties. Consumers are just becoming aware of the medicinal properties of exotic mushrooms. Numerous value-added products have been developed, including facial creams, teas, encapsulated mushrooms and mushroom parts, soups, and dried mushroom products. Recent research has shown that lentinan is as much as 2.6 times greater in log-grown mushrooms than it is in substrate-grown mushrooms. Strain and tree species interactions also influence the content of lentinan in mushrooms. From a marketing perspective, this is a bonus for log-mushroom producers.

The quality differences between log- and substrate-grown mushrooms may be marketing points as consumers become more sophisticated about mushroom purchases. Log-grown mushrooms are often meatier and sometimes have a longer shelf life. The health benefits will become more apparent as more nutrition and health magazines tout the benefits of lowering cholesterol without the potential for liver damage and increased survival rates of cancer patients.

Marketing Options

The market for fresh shiitake mushrooms includes supermarkets, produce buyers, restaurant suppliers, produce wholesalers, whole food and health food stores, and farmers markets. Early and small-scale production can be marketed to friends and coworkers or to online business swap trader sites. Dried mushrooms, mushroom products, and unfruited logs can be sold on business and other commercial Web sites.

Before establishing any production system, markets should be investigated and evaluated. Talk with buyers to determine their needs and if there is a market within a reasonable distance of your production area. Another issue is the frequency and quantity requirements of buyers. Supermarkets may demand a minimum supply of 700 pounds per week and most buyers insist on fresh weekly supplies. Some buyers want daily delivery. Determine in advance what you can and cannot accommodate.

Shiitake mushrooms can also be dried and made into value-added products sold at health

food stores. Value-added products such as supplements are expensive to create and require sterile rooms and specialized equipment.

A mushroom marketing study completed in Georgia in 2002 concluded the following:

- Economies of scale are important to profitability.
- Value-added products such as added mushrooms to fast-food products, meals ready-to-eat, pharmaceuticals, and alternative substrate production must be considered.
- E-commerce sites similar to Harry and David's Fruit of the Month Club offer sales opportunities. Storefronts such as Yahoo and e-Bay should be used for test marketing, use of sales, and tracking tools.
- For large-scale production to be successful in a region, a large-scale spawn production facility should be located nearby.
- Research on strains, their improvement, selection, breeding, and quality control; substrate development; and species selection should be nearby and funded at colleges and universities.
- Creation of a Mushroom Commodity Commission operated and controlled by growers will help certify mushrooms as organic, provide bulk pricing for supplies, and help with marketing.
- Training programs should be available for new growers, laborers and management, distributors, retailers, chefs, Extension agents, and consumers.

This study examined the economic issues surrounding the development of a specialty mushroom industry in Georgia. For this purpose, the conclusions are sound. Individual growers who wish to enter the market slowly and build the industry to the levels suggested in the study will have to carve their own markets and develop production strategies that work in their region of the United States.

Cost of Production

Shiitake production has many inputs. Producers often have many of the items already available or can build them cheaper than they can buy them. Table 1 describes the inputs needed to establish a 1,000-log operation by inoculating 500 logs the first year and 500 logs the second year. The 2-YEAR COSTS include everything needed (and that will be used up) to establish the 1,000-log operation over 2 years. These costs will be incurred each time logs are inoculated after the first 2 years. The ESTABLISHMENT COSTS are for tools and equipment for inoculation, log storage, irrigation, and soaking and cooling mushrooms. These costs will only be incurred at startup or if items need to be replaced at a later date.

To establish a 500-log per year operation, total costs for the first 2 years are $10,938. The returns would be $9,000, assuming a $4.50 sales price. If logs are established in year three and beyond, the additional cost of production would be $6,175 for the next 2 years. In other words, by the end of year 4, input costs would be $17,113 and returns would be $18,000. After year 6, returns/1,000 logs will total $3,712.

Total returns can be increased by cutting your own logs, using family labor, and making your own shade house. Cutting 500 logs will take two people about 3 8-hour days or 48 hours. If you have access to the appropriate wood species, this may be a cost savings. Pine stands make a good cover and can be used for shade instead of a shade house. However, to fruit on a weekly basis, you will need a fruiting house. This could be a garage, shed, basement, or other small building that will tolerate added moisture. About 2 square feet are required for each log fruited. For a 1,000-log operation, 62 logs will be fruited weekly (1,000 logs/16 weeks between fruiting). A 5 x 10

foot building with racks or shelves would accommodate this volume. The facility would need to be ventilated, heated, and cooled with some form of mist added. The elimination of a shade bay and frame (if you have other ways to shade the logs) would more than pay for a structure and heating and cooling equipment.

Table 1. Outdoor Shiitake Mushroom Log Production Budget for 500 Logs/ Year for Two Years[1]

Item	Quantity	Price/Unit	Total
2-YEAR COSTS			
Logs 2-7" dia., 3-4 feet long	1000	0.75	750.00
Spawn	50 bags	15.00	750.00
Wax (food grade cheese)	40 lbs	2.00/lb.	80.00
Drill bits (7/16" collar stop)	3	12.00	36.00
Propane refills	5	17.00	85.00
Burlap 60"x 100 yds.	4 rolls	100.00	400.00
Utilities (water, electricity)	1000	.14	140.00
Picking containers	10	5.00	50.00
Packaging (variable/boxes)	400	.25	100.00
Transportation	400	.50	200.00
Labor (establishment)			1,400.00
Labor (harvest & marketing)			
20 logs/week, 3 hours/week	312 hrs/2 yrs	7.00/hour	2184.00
Subtotal 2 year Costs			6,175.00
ESTABLISHMENT COSTS (Equipment 4+ years life)			
Inoculation tools	4	30.00	120.00
Wax basters	2	10.00	20.00
Anglegrinder/adapter	1	110.00	110.00
Gas stove	1	40.00	40.00
Propane tank with gas	1	45.00	45.00
Wax kettle (cast iron)	1	50.00	50.00
Shade bay frame 20'x10'x10'	5	500.00	2500.00
Shade cloth (85%)	1320 sq. ft.	.65/sq. ft.	858.00
Irrigation/ hoses	8	10.00	80.00
Soak tank	1	100.00	100.00
Irrigation timers	8	30.00	240.00
Refrigerators (used)	2	300.00	600.00
Subtotal Establishment costs			4,763.00
TOTAL startup costs			**$10,938.00**
Mushroom sales (2 yrs)	**2,000#**	**4.50**	**$9,000.00**

[1] This data is obtained from current prices and does not include the cost of a fruiting building. To obtain these yields, a fruiting room is necessary. Costs and prices will vary based on vendor, petroleum prices and market demand. Costs tend to increase over time and for most agricultural crops, prices for the crop rarely keep up with input costs.

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Appendix A
Glossary

Ambient air temperature: The air temperature all around, outside the log.

Bark Blow-off disease: Caused by *Hypoxylon* spp. and results in decreased yields or total loss of the log. Appears initially in the form of small black dots in the grooves of the bark. It eventually develops into hard black pustules in the bark. Generally this fungus enters the wood prior to inoculation. Its growth can be prevented by keeping the bark of the logs dry before inoculation.

Caps: The top portion of the fruiting body of shiitake mushrooms.

Colonize: The establishment of the spawn within the log.

Contamination: The invasion of foreign or weed fungi into the log.

Cord: A volume of wood with logs 4 feet long, stacked 4 feet high and 8 feet long. An average hardwood cord of wood weighs between 5,800 and 6,000 pounds. About 240 logs that are 40 inches long and 3 to 8 inches in diameter make up a cord.

Dormant: This is when a tree is alive but not actively growing. Deciduous trees or those that lose their leaves are usually dormant from the time they are in full fall leaf color until bud break in the spring.

Dowel spawn: Spawn that is cultivated on wooden dowels 5/16 inch in diameter and 3/4 inch long.

Fruiting: When the spawn has sufficiently completed spawn run and the environmental and log conditions are adequate for that strain, shiitake mushrooms will fruit or produce a fruit body. The fruit body is the mushroom.

Fruit body: The mushroom.

Fungal cultures: A single organism or strain of shiitake or other fungus.

Fungus: Life form that is a parasite of living organisms or feeds upon dead organic material.

Hardwood: Wood of a broad-leaved tree possessing true vessels in contrast to the softwood of a needle-bearing conifer that lacks vessels.

Inoculation: The introduction of spawn into a medium, logs, sawdust, etc.

Inoculum: The spawn or fungus.

Laying the logs: The placement of the shiitake logs after they have been inoculated.

Laying yard: The location where inoculated logs are placed until fruiting and sometimes until the log has completely decomposed.

Mature laying yard: The location where inoculated logs that have completed their initial spawn run are placed.

Mycelia: plural of mycelium.

Mycelium: The vegetative part of a fungus made of a mass or network of threadlike tubes.

Pinning: The initial fruiting stage of the mycelium as the fruiting body begins to protrude out of the log or other media.

Sawdust production: The production of shiitake mushrooms in an artificial log made up of sawdust, grains, and other materials. Generally, sawdust production is an indoor operation.

Shade cloth: Material used to provide shade for the logs. It can be made up of many types of material including burlap, spunbonded polyester, and vinyl.

Shiitake mushrooms: *Lentinula edodes*, commonly known as the black mushroom used in Oriental cooking.

Spawn: Pure culture mushroom mycelium on a suitable sterilized substrate such as various agars, grains, or wood chips used for inoculation.

Spawn run: Incubation period of shiitake mycelium prior to fruiting.

Spores: A small reproductive body that comes from the gills of the mushroom. It is similar in purpose to a seed.

Trichoderma: An undesirable green mold, which frequently contaminates logs under conditions of high moisture, poor ventilation and/or dry conditions.

Weed fungi: Fungi other than shiitake that invade a log inoculated with shiitake spawn.

Appendix B
Grower Associations/Cooperatives

American Mushroom Institute
One Massachusetts Avenue, N.W., Suite 800
Washington, D.C. 20001
(202) 842-4344; (202) 408-7763
http://www.americanmushroom.org

Appalachian Mushroom Growers Association
Rt. 1, Box 30 BYY
Hayward, VA 22722
(504) 923-4774

Canadian Mushroom Growers Association
660 Mill Rd., R.R. #4
Guelph, Ontario, Canada N1H 6J1
(519) 829-4125
E-mail: info@canadianmushroom.com
http://www.canadianmushroom.com

Carolina Exotic Mushroom Association
Jessica Lowenadler
P. O. Box 11280
Columbia, SC 29211

Mississippi Natural Products Association
791 Ferguson Mill Road
P.O. Box 30
Monticello, MS 39654
(601) 587-8012

North American Mycological Association
6615 Tudor Ct.
Gladstone, OR 97027-1032
(503) 657-7358
http://www.namyco.org/index.html

SHII-GAW (Shiitake Growers of Wisconsin)
1-800-792-6220
http://www.shiigaw.org

Shiitake Mushroom Center
Tom Kimmons
366 Brown Rd.
Shirley, AR 72153
(501) 723-4443

The Shiitake Association
c/o John Sherwood
5698 Werkshire
Milford, OH 45150
(513) 831-1468

Appendix C
Spawn and Equipment Suppliers

Amycel
P.O. Box 637
Avondale PA 19311
(610) 869-4041
http://www.amycel.com

Far West Fungi
P.O. Box 1333
Goleta, CA 93116
http://www.farwestfungi.com

Field and Forest Products
N3296 Kozuzek Rd.
Peshtigo, WI 54157
(715) 582-4997, (800) 792-6200
http://www.fieldforest.net

Fungi Perfecti
P.O. Box 7634
Olympia, WA 98507
(360) 426-9292, (800) 780- 9126
http://www.fungi.com

Hardscrabble Enterprises
Rt. 6, Box 42
Cherry Grove, WV 26804
e-mail: Hardscrabble@mountain.net

L.F. Lambert Spawn Co.
P.O. Box 407
Coatesville, PA 19320
(610) 384-5031
http://www.lambertspawn.com

Mushroom Harvest
Athens, OH
E-mail: mushroom@frognet.net

Mushroompeople
P.O. Box 220
Summertown, TN 38483
(931) 964-2200, (800) 692- 6329
http://www.mushroompeople.com/

Mycosource, Inc.
21 Maple Avenue
Toronto, ON Canada M4W 2T5
(416) 402-9755, (416) 963-5520
http://www.mycosource.com

Northwest Mycological Consultants, Inc.
702 NW 4th St.
Corvalis, OR 97330
(541) 753-8198
http://www.nwmycol.com

Sohn's Oak Forest Mushrooms
P.O. Box 20
Westfield, WI 53964
(608) 296-2456

Swayne's, Inc.
P.O. 257 Starr Road
Landenberg, PA 19350 19348
(610) 444-0888

Sylvan America, Inc.
199 Nolte Drive
Kittanning, PA 16201
(800) 323-4857
http://www.sylvaninc.com/

Unicorn Imp. & Mfg. Corp.
P.O. Box 461119
Garland, TX 75046
Tel: 1-972-272-2588, Fax: 1-972-272-8883
http://www.unicornbag.com

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