Producing **Shiitake Mushrooms**

A Guide for Small-Scale Outdoor Cultivation on Logs

*The two most popular mushrooms in the world are the common button mushroom (*Agaricus *spp.) and the shiitake or black forest mushroom (*Lentinus edodes*), shown below. The shiitake, meaning "mushroom of the* shii *(oak tree)" in Japanese, is highly prized in Asia for its flavor and reputed medicinal value. It is a major agricultural commodity in Japan, where about half the world's supply of shiitake mushrooms is produced.*

Formerly, the only shiitake mushrooms that could be purchased in the United States were dried and imported. Shiitake mushroom production began in this country about 25 years ago, and with it came a new demand for fresh mushrooms. This demand is increasing rapidly as consumers discover the delicious, meaty flavor of fresh shiitake mushrooms. Now that these mushrooms are commanding an average wholesale price of $5 to $9 a pound, thousands of farmers and investors across the country are interested in producing them.

For individuals interested in production on a hobby scale or for limited local sales, growing shiitake mushrooms can be quite rewarding. Commercial production, however, requires a substantial commitment of time and money. As with any agricultural commodity, profitability depends on the grower's production and marketing skills, as well as on market supply and demand. Shiitake production is still fairly new in this country, and new strains (varieties) and methods of production are being developed. The profitability of production depends on the efficiency of the operation, the availability of substrate materials (logs or other organic material), and labor. Growers should experiment on a small scale before committing substantial resources to commercial production.

The shiitake mushroom is a wood-decay fungus grown on logs or in bags of nutrient-enriched sawdust or other organic materials. Bag culture is a highly specialized process that must be conducted in buildings with close control of temperature, light, and moisture. The risks of contamination and loss are much greater with bag culture than with log growth, particularly for inexperienced growers. This publication deals solely with outdoor production on logs and explains techniques suitable for small producers and hobbyists.

Areas Suitable for Production

In their natural environment, shiitake mushrooms grow on dead hardwood tree logs in a warm, moist environment. The combination of warm temperatures and high rainfall promotes rapid growth of the shiitake **mycelium** (see "Key Terms," p. 2), the mass of thread-like structures from which the mushroom grows. A sudden change in temperature or moisture triggers the fruiting response, resulting in mushroom production.

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Key Terms

Backing cord	Ropes of a spongy foam material designed to be inserted between fresh sections of concrete to allow for expansion. Used in shiitake production to make plugs for capping the holes in logs.
Fruiting	The formation of the edible fruiting bodies of a fungus—that is, the mushrooms.
Heartwood	The old, dark-colored portion of the wood in the center of a tree trunk or limb.
Humidity blanket	A nonwoven, porous, synthetic material used to control evaporation from the logs.
Incubation	The period during which the logs are maintained under conditions favorable for the mycelium to grow throughout the sapwood of the log. Also known as spawn run.
Inoculation	The process of introducing the mushroom mycelium into the wood.
Mycelium	The mass of interwoven filaments that form the vegetative portion of a fungus.
Pinning	The process of forming primordia.
Primordia	Little mushroom buds visible on the surface of the logs; the earliest stage of mushroom development.
Sapwood	The young, light-colored portion of the wood near the outside of a tree trunk or limb.
Sawdust plunger	Tool for injecting sawdust spawn into holes in logs.
Shade cloth	A heavy synthetic fabric, usually black polypropylene, used to shade the logs.
Spawn	The vegetative stage of mushroom mycelium growing on a substrate, such as sawdust or wooden dowels.
Spawn run	Incubation period during which the vegetative stage of the mycelium grows throughout the sapwood of the log.
Strain	A selected mushroom variety.

In western North Carolina, these conditions occur naturally, but because shiitake is not native to North America, hardwood logs must first be inoculated with shiitake **spawn.** Once that is done, fruiting occurs naturally, primarily in spring and fall because of seasonal rains and temperature changes. Shiitake mushrooms can also be produced on logs in eastern North Carolina, but because of the higher temperatures in that part of the state, it is important to have adequate means of maintaining a high moisture level in the logs.

Tree Selection and Log Preparation

Because shiitake mushrooms grow on logs, many growers make mushroom production part of their woodlot management plan. If logs must be purchased, care should be taken that the proper tree species are selected, only healthy trees are cut, and the logs are handled properly.

Shiitake mushrooms will grow on a wide range of tree species, with varying degrees of success. In North Carolina, oaks (red, white, and chestnut) and sweetgum are excellent mushroom producers. Shiitake mushrooms grow best on logs with a high wood density, a high ratio of **sapwood** to **heartwood**, and bark that is strong but not too thick. Growers are advised to experiment with the logs available to them. Logs from different tree species require different management strategies. For example, thin-barked logs must be handled carefully to prevent damage to the bark. Logs with thin bark also lose moisture faster than logs with thick bark; therefore, log moisture content must be monitored closely.

Trees should be cut while they are dormant, preferably in the late winter or early spring before budbreak, for two important reasons. First, the shiitake mycelium requires carbohydrates for growth, and carbohydrates in the wood are at their highest levels when the tree is dormant. Second, the bark of the logs must be intact and must adhere to the logs well. If the trees are cut after the sap begins to flow in the spring, the bark will have a tendency to "slip" and can be damaged easily. Some growers have reported success with trees cut in late fall.

Once the trees have been cut, it is important to keep the moisture content of the wood high and the bark dry until the logs are inoculated with the shiitake fungus. Trees cut in late winter (November to January) should lie for 10 days with branches intact before being cut into logs; logs should be inoculated within 90 days of cutting. Trees cut in early spring (February to March) should also be allowed to lie for 10 days with branches intact before being cut into logs, but they should be inoculated within one month, to prevent the establishment of contaminating fungi. If the trees must be cut into logs at the time of felling, they should be inoculated within two weeks. Growers should also take measures to prevent moisture

loss. If the weather is dry and windy, store the logs in a bulk pile and cover them loosely with burlap, muslin, or other porous material. If the weather is rainy, stack the logs loosely to permit good air circulation, and cover them loosely with plastic sheeting.

Most small-scale producers rely heavily on manual labor, so it is important to prepare logs that are easy to handle. Logs that are 3 to 4 feet long and 4 to 8 inches in diameter are best. The logs must be from live, healthy trees that are free of decay. They should be fairly straight and uniform, with the bark intact. Using logs with large sections of bark that have been damaged or removed during harvest is not recommended.

Spawn Selection

The shiitake fungus is introduced into logs by inserting the mycelium in the form of spawn, a process known as **inoculation**. A listing of current spawn suppliers is available from your county Cooperative Extension Center. Spawn is most readily available in two forms: sawdust and dowels (also called "plug spawn") (Figure 1). There are a few spawn suppliers selling a product called "thimble spawn." This product comes in plastic sheets with little wells containing compressed sawdust spawn with a foam plug on top.

All of these materials are inoculated with the shiitake fungus by the supplier and are ready to use upon receipt. They are covered with mycelium, a fuzzy, white growth similar in texture to bread mold. The spawn can be stored in a refrigerator or cold room for several months but should be held at room temperature for several days before inoculation. Sawdust spawn is usually sold in bags or bottles. Dowels are usually sold in bags of one thousand, and thimble spawn is usually sold in sheets of six hundred. Results from some studies suggest that sawdust spawn produces mushrooms faster than dowels and is generally less expensive. Many new producers, however, find that dowels are easier to use and have a higher rate of success because moisture control is not quite as critical when using dowels. Thimble spawn inoculation is the slowest of the three methods but does not require the sealing step.

Figure 1. Shiitake spawn is available in sawdust (top) or on wooden dowels (bottom).

Many companies in the United States sell shiitake mushroom spawn, but few data have been published on the performance of the various **strains** in the Southeast. Tree species and growing environment greatly affect the performance of shiitake strains. Be sure to ask the supplier for spawn suitable to your area. Most suppliers sell three types of strains according to the weather conditions under which they fruit: warm, cold, or a wide range of temperatures. Purchasing several strains from two or three suppliers increases the chances of finding a strain suited to your conditions.

Inoculation

Logs are usually inoculated in late winter or early spring, shortly after they have been cut. In western North Carolina, inoculation can be started in November and should be completed by late March. Farther east, inoculation should be completed by February or March. When logs are fresh, their moisture content is high, and competing wood decay fungi have probably not become established. Log moisture content should be between 35% and 55% at the time of inoculation. (Methods for determining log moisture content will be discussed later).

Sawdust or dowels are placed in holes drilled into the logs (Figure 2). Spawn suppliers usually provide detailed information on hole depth and diameter. The general practice is as follows: starting 1 inch from the end of the log, drill holes 3 inches apart in rows along the length of the log, with 3 to 4 inches between rows. The holes should be staggered in a diamond pattern to ensure rapid growth of the fungus throughout the log (Figure 3). Closer spacing increases the rate of colonization and results in more rapid mushroom production; however, spawn costs are also greater.

Figure 2. Holes are drilled in the log with a high-speed drill.

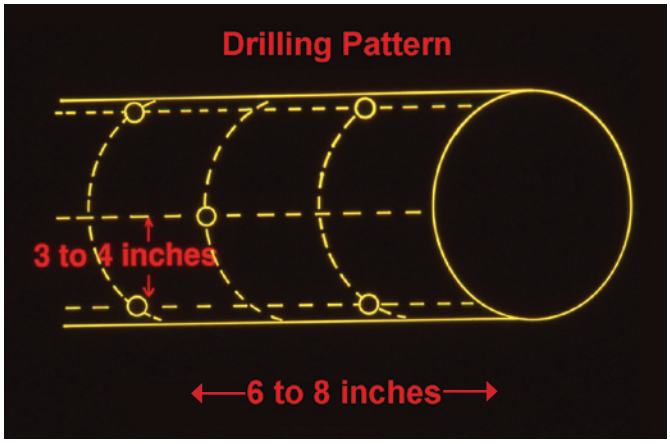

Figure 3. Pattern for drilling holes in logs.

Figure 4. Dowels are pounded into the holes with a hammer.

An electric hand drill can be used to inoculate a small number of logs. For a large number of logs, a converted angle grinder or a high-speed drill (operating at 6,000 to 10,000 rpm) made especially for this purpose would be more practical. When using dowels, appropriately sized drill bits can usually be purchased through the spawn supplier. For sawdust, use a bit that is the same diameter as the **sawdust plunger** used to inject the spawn into the holes.

Spawn should be placed in the holes immediately after they have been drilled, to prevent contamination by other fungi (Figure 4). Immediately after the spawn has been inserted, seal the holes with hot sealing wax or foam plugs to prevent the spawn from drying. Many growers also apply wax over the ends of the logs to seal in moisture.

Cheesewax and beeswax are preferred because they stay flexible when dry. Some growers use the more readily available paraffin wax, but it is brittle and may flake off when dried. The wax must be very hot when applied, to ensure an airtight, flexible seal. If the wax is not hot enough, pinholes may develop as the wax cools, and the seal will be thick, opaque, and easy to knock off. Small electric deep-fat fryers or camp stoves may be used to heat the wax. In either case, use extreme caution to prevent fire, and keep a fire extinguisher close at hand. Hot wax may be applied to the filled holes with special wax applicators, which look like kitchen turkey basters, or with a brush (Figure 5). Be sure to use a natural-hair brush because most synthetic brushes will melt in the hot wax.

As an alternative, foam plugs may be made to insert after the spawn has been placed in the holes. The plugs can be cut from the foam backing cord made for filling cracks in concrete slabs. Backing cord is available through building suppliers. A razor blade can be used to easily cut the foam backing cord into ¼-inch to ½-inch discs. Although using the foam plugs is safer than working with wax, it takes much longer to make the plugs and insert them than it does to melt and apply hot wax. Also, some growers have reported that squirrels and birds sometimes remove the plugs from the logs.

Figure 5. Holes filled with spawn are sealed with hot wax.

After the logs are inoculated, they should be marked to indicate date of inoculation and spawn strain. Small metal or plastic tags can be marked and nailed into the ends of the logs for this purpose. Some growers use a color-coded method to help them distinguish different groups of logs.

Spawn Run

After inoculation, the logs should be stacked and the fungus given time to spread throughout the sapwood. This process, known as **spawn run** or **incubation**, takes from six to 18 months, depending on fungus strain, the amount of spawn in each log, the size and moisture content of the log, and ambient air temperature. The goal is to provide favorable conditions for the shiitake mycelium so it can spread through the logs as quickly and evenly as possible. At the same time, conditions should be made as unfavorable as possible for competing fungi. Productivity of the logs depends on how well the shiitake fungus establishes itself during spawn run. Providing optimum growing conditions at this time is crucial for successful production.

For spawn run, the logs should be placed in a warm, shady area that has good air movement but is protected from strong winds. A shade canopy of pine, hardwoods, or shade cloth providing about 80% shade is desirable. Do not attempt to grow shiitake mushrooms in total darkness; some light is required for spawn run and fruiting. The optimum quantity and quality of light required have not been reported and would be difficult to measure, but if you can read a hard copy of this publication while standing next to your logs in the middle of the summer in midafternoon, there is enough light. However, too much light is undesirable, because it encourages growth of some competing fungi, heats the logs to temperatures that are unsafe for the mycelium, and causes excessive moisture loss. Special **humidity blankets**, available through some spawn suppliers, can be placed over the logs to help hold in moisture.

Stacking Methods

There are many log-stacking systems. The system you choose should depend on your preference and the spawn run site. Two common systems are crib stacks and lean-to stacks. Crib stacks are built of horizontal layers of logs laid perpendicular to each other (Figure 6). Each layer contains four to eight logs in stacks about 4 feet high. Uninoculated logs should be used as the base to keep inoculated logs off the ground. Although these stacks use space efficiently, allow for good air movement, and are self-supporting, there is a pronounced difference in temperature and humidity between the top and bottom layers of the stack.

Lean-to stacks are composed of vertical rows of logs supported against a horizontal rail or wire (Figure 7). Lean-to stacks are the best method to use when your land is hilly or steep. They do not require lifting logs to various heights, as with the crib stack system, and picking is easier. However, lean-to stacks require a large amount of space, and there are differences in temperature and humidity between the two ends of the logs. There are many variations on both of these stacking methods.

Figure 6. Crib stacking system..

Log Moisture Content

The optimum log moisture content for shiitake mycelium growth is 35% to 55%. The shiitake mycelium will die if the moisture content of the log drops below 25%. Water should be readily available at the production site so that the logs can be irrigated if necessary to prevent excessive drying during spawn run and to induce fruiting later in the production cycle. If the log moisture content drops below about 40% or there is no rain for a two- to three-week period, the logs should be immersed in water or sprinkle-irrigated.

The easiest way to monitor log moisture content is to prepare reference logs that can be checked periodically. Reference logs are representative logs selected at the time of log cutting. Choose two or three logs from each load or source of logs. Weigh these logs as soon as possible, record their weights, and permanently identify them by painting a number on them or attaching an aluminum tag. Then treat them like all the other logs. These logs can be weighed whenever an estimate of current log moisture content is required.

Choose another set of logs to use in measuring initial moisture content. Again, select two or three logs from each load or source. Soon after the logs have been harvested, cut thin slices (about 1 inch thick) across the grain at least 6 inches from the ends of the logs. Put the slices in a plastic bag immediately to prevent them from losing moisture until they can be weighed. Weigh the slices to get their initial fresh weights. Then place the slices in an oven at 200°F for six to 12 hours. Reweigh several of the slices and put them back in the oven for two-hour intervals, repeating the process until they stop losing weight. Then reweigh all the slices to find their oven-dry weights. The fresh weight minus the oven-dry weight equals the water weight that was present in the sample initially:

Water weight = fresh weight – oven-dry weight

For example, if the initial fresh weight of the slice was 8 ounces and the oven-dry weight was 4.2 ounces:

Figure 7. Lean-to stacking system.

Water weight = 8 oz – 4.2 oz = 3.8 oz

To calculate the initial moisture content of the logs, divide the water weight by the initial fresh weight of the slice and multiply by 100:

$$\text{Initial moisture content} = \frac{\text{water weight}}{\text{fresh weight}} \times 100$$

For this example,

$$\text{Initial moisture content} = \frac{3.8 \text{ oz}}{8 \text{ oz}} \times 100 = 47.5\%$$

(round to 48% for ease of subsequent calculations)

Average the initial log moisture contents from all the sample slices to get the average moisture content for all the logs.

To calculate the dry weight of each of the reference logs, multiply the fresh weight of the log by 1 minus the average moisture content divided by 100:

$$\text{Dry weight} = \text{fresh weight} \times \left(\frac{1 - \text{average moisture content}}{100}\right)$$

For this example, if the fresh weight of a log is 23 pounds:

$$\text{Dry weight} = 23 \times \left(1 - \frac{48}{100}\right) = 23 \times (1 - 0.48) = 11.96 \text{ pounds}$$

Keep a notebook with the date, reference log number, initial fresh weight, dry weight, current weight, and log moisture content. Many growers write the dry weight and the reference log number on an aluminum tag and attach it directly to the reference log. Whenever it is necessary to know the log's moisture content, it can be calculated by subtracting the dry weight of the log from its current weight to get the water weight. Then divide the water weight by the current weight and multiply by 100.

$$\text{Log moisture content} = \frac{\text{current weight} - \text{dry weight}}{\text{current weight}} \times 100$$

For example, if the current weight of the reference log is 20 pounds and we found earlier that the dry weight was 11.96 pounds:

$$\text{Log moisture content} = \frac{20 - 11.96}{20} \times 100 = 40.2\%$$

As the shiitake mycelium decays the logs, the dry weight of the logs changes dramatically. Therefore, this method provides a reasonable estimate of the moisture content for only the first year or so after inoculation.

Moisture Management

Management of log moisture content during spawn run has a major influence on the future productivity of the logs. The objective is to keep the interior moisture content between 35% and 55% while keeping the bark as dry as possible. An experienced grower can tell when logs need to be irrigated by their feel and appearance. The beginner, however, should carefully monitor log moisture content as described previously. An overhead sprinkler irrigation system fitted with microsprinkler heads is usually used to maintain log moisture during spawn run. When irrigation is required, soak the logs thoroughly. It is better to irrigate for long periods of time (six to 12 hours) every week or two than to irrigate for an hour or two every few days. Extending the time between irrigation periods allows the bark to dry, creating unfavorable conditions for the most common competing fungi and molds.

Log Temperature

Log temperature is also important for spawn run. For most strains, the optimum temperature for incubation is 72°F to 77°F. Irrigation can quickly lower the log temperature if necessary, and solar energy can be used to warm the logs by orienting them so that they intercept the most sunlight. Be careful not to overheat them, though.

Fruiting

Fruiting of the shiitake fungus occurs after the mycelium has thoroughly colonized the logs. One sign that spawn run is almost complete is the appearance of mycelium on the log ends. The mycelium is usually white and fuzzy, but it may be brown from exposure to the air. The bark and outer wood will also feel slightly spongy, but the most obvious sign is the appearance of primordia, the beginnings of mushrooms.

If the logs are left alone, seasonal changes in temperature and moisture will cause fruiting to occur naturally. For a steady supply of mushrooms, however, it is necessary to control fruiting time. This control can be achieved by carefully selecting shiitake strains, soaking or sprinkle-irrigating the logs at specific times, and using some type of structure to provide some control of temperature. To avoid contamination of areas of the log that have not been thoroughly colonized by mycelium, wait one year after inoculation to attempt forced fruiting.

Many growers restack the logs before fruiting occurs to provide more space for the mushrooms to grow and to facilitate harvesting. If rain is not in the forecast when fruiting is desired, the logs can be irrigated or soaked in water (Figure 8) for 24 hours to induce fruiting. As the logs dry, **pinning**—the appearance of mushroom primordia—occurs. Mushrooms will usually appear within a week of soaking. Excessive moisture will lower mushroom quality, and low

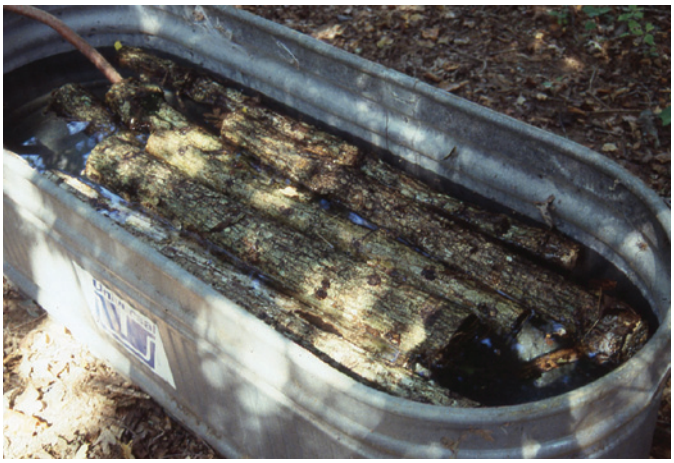

Figure 8. Tank for soaking logs.

humidity and drying winds will stop the mushrooms from growing. If humidity is too low, logs should be sprinkled two to three times per day to maintain moisture levels. If rain is forecast, protect the logs with humidity blankets or by building a simple sheet-plastic roof over the stacks. Elevate the blankets or sheet plastic above the logs so they don't touch the developing mushrooms and to ensure good air circulation around the logs.

It is possible to force fruiting on a fairly regular cycle. This tactic is recommended for commercial producers to ensure a continuous supply of mushrooms throughout most of the year. For forced fruiting, logs are soaked every four to eight weeks, up to three times per year. For winter production, the logs must be soaked and then stored in a heated building (59°F to 68°F during the day; 50°F to 59°F at night), with the humidity kept between 60% and 85%. The fruiting season can be further extended by selecting strains with different fruiting requirements, using warm-weather strains in the summer and cool-weather strains in the winter. Logs that are allowed to fruit naturally will produce for three to five years. Forced fruiting reduces the productive life of the logs to two or three years.

Pest and Disease Management

A number of diseases can destroy the shiitake fungus or compete with it for water and nutrients. Some insect and animal pests can also reduce yields or quality.

Fortunately, if the environment in and around the logs is properly managed, disease fungi should not be much of a problem. The most common disease fungi of shiitake in North Carolina are the *Trichoderma*, referred to as green mold; *Hypoxylon*, known as black mold; and *Coriolus versicolor*, known as turkey tail. To minimize disease problems, it is important to provide optimum growing conditions for the shiitake mycelium during spawn run.

Development of green mold can become a problem in production throughout North Carolina. To control green mold, only irrigate logs when needed, and remove and burn contaminated logs. Black mold is most common in central and eastern North Carolina. To prevent development of black mold, do not use old trees or limbs for inoculating. Maintain the moisture level in the logs, and do not allow them to become dry. Do not expose the logs to direct sunlight. A dense spacing of holes will allow the shiitake fungus to thoroughly colonize the logs, thus limiting black mold contamination. Remove logs that become contaminated, and burn them immediately. Turkey tail fungus grows on bruised, bare parts of logs as well as on the ends. Only fresh logs should be used, and all parts of logs where there is no bark should be waxed, including the ends.

Insects that might present a problem include termites, bark beetles, and springtails. Slugs and snails are probably the most commonly encountered pests of shiitake. They cause serious damage by feeding directly on the mushroom caps. Methods of control include sprinkling lime and wood ash around the stacks, putting a layer of gravel on the ground around the stacks, removing all dead leaves and other organic debris, and keeping the soil surface dry. Birds, squirrels, and deer also feed on shiitake mushrooms. Very creative strategies are required to protect the mushrooms from these animals. Growers have reported some degree of success in controlling wildlife damage by erecting scarecrows, keeping dogs in the area, leaving a radio on, or constructing a tall fence.

Harvesting

Daily harvesting is required during fruiting periods (Figure 9). Mushrooms should be picked while there is still a small curl at the edge of the cap, usually five to seven days after the mushroom first appears. Mushrooms should be cut or twisted off at the base of the stem. Then they should be gently placed into smooth-sided, clean, vented containers. Do not stack the mushrooms more than six inches high, to prevent bruising. Cool the mushrooms to a temperature

Figure 9. Mushrooms ready for harvest.

between 32°F and 36°F as soon after harvest as possible, and maintain the relative humidity at about 85%. Under these conditions, the mushrooms will store well for at least two weeks. They can also be dried very successfully. The simplest way to dry them is to place them in a forced-air drier at about 120°F.

Resting Period

After harvest, the mycelium must be given time to accumulate nutrients for the next fruiting cycle. In forced-fruiting systems, the logs should rest for four to eight weeks. If forced to fruit too soon, the mycelium will be stressed, few mushrooms will be produced, and future production will probably be reduced. During the period of rest and regrowth, keep the logs warm, and maintain their moisture content between 30% and 40%. Under natural conditions, logs will usually produce two crops per year, one in the spring and one in the fall. Forced fruiting can result in three to six crops per year. The number of fruiting cycles depends on tree species, strain of shiitake used (e.g., warm weather, cold weather, etc.), log size, temperature, and moisture.

Packaging

Bulk shiitake mushrooms are commonly sold in vented, waxed cardboard boxes in amounts of 3 to 5 pounds. They are also sold in small 2- to 4-ounce retail packages consisting of trays wrapped in a gas-permeable plastic film.

Marketing

Many people can grow shiitake mushrooms. The successful producers, however, are those who can also market them. If production is small and seasonal, marketing efforts should be concentrated in the local area. Marketing opportunities include high-quality restaurants, health-food stores, local supermarkets, farmers' markets, tailgate markets, newspaper ads, and direct sales. Before large-scale production is initiated, start negotiations with food service and produce brokers, or negotiate directly with large-scale buyers of fresh produce. Some large-scale shiitake mushroom producers may also be interested in marketing other growers' mushrooms. Your county Cooperative Extension Service agent or a North Carolina Department of Agriculture and Consumer Services marketing specialist may be able to advise you on opportunities in your area.

Production Economics

The final decision on whether to grow shiitake mushrooms commercially rests on economics. Based on experiences in other areas of the United States and overseas, a cord of approximately 125 logs will yield about 500 pounds of mushrooms, or 4 pounds per log. At a selling price of $5 per pound, mushrooms from one cord of wood should generate $2,500.

Initial cost for obtaining one cord of logs by either cutting them or buying them is approximately $125. The spawn for inoculation costs approximately $125. Production costs for labor, supplies, marketing, and amortized costs of refrigeration and irrigation amount to an additional $800 to $1,300. Annual returns to the grower for his or her labor, capital, and management should be approximately $500 to $2,125 per cord of logs fruited naturally, or $1,900 to $3,700 per cord of logs fruited by forcing.

Growing shiitake mushrooms can be profitable at today's market prices. Profit margins, however, will probably decrease as national production increases and supply approaches demand. The small-scale producer will face competition from large-scale producers as well as from companies that grow shiitake mushrooms on sawdust. The successful grower will be one who produces a quality product at minimum cost while developing and maintaining an effective marketing strategy.

Reference

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