



# Growing Shiitake Mushrooms

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## Introduction

Shiitake is an edible mushroom that grows on wood from a variety of tree species. Due to its ease of cultivation and its pungent flavor, Shiitake is being considered as an alternative crop in many areas of the United States. Shiitake have been used in the Orient for about 2000 years, but have only been commercially cultivated since 1940. About 160,000 metric tons are produced annually in Japan, half of which is dried and exported. It represents a two billion dollar industry which employs about 200,000 people.

In the United States, shiitake is used in oriental restaurants and is often sold in oriental, gourmet and health food stores. Over \$15 million of Japan's shiitake mushroom production during 1984 was exported to the U.S. The demand for Shiitake is increasing as consumers are being introduced to the mushroom which is more chewy, aromatic and flavorful than the common button mushroom. Over 2.1 million pounds of shiitake was produced in this country during 1986 and nearly 3 million pounds in 1987.

As an alternative enterprise in the United States, Shiitake represents a way to utilize a forest resource that, in many cases, is considered a weed. Growing Shiitake involves utilization of low quality hardwoods; trees of small diameter (three to six inches) that normally are either left in the woods after conventional logging, cut and sold as low-value pulpwood, harvested as firewood, removed as competition or left as unproductive land. Utilization of this resource would also present opportunities for small woodlot improvement.

Much of the shiitake production in the U.S. occurs in Virginia, Ohio, Pennsylvania and California. Growers range in size from small operations of a few logs to large corporations with hundreds of thousands of logs. In Oklahoma, low quality hardwoods, suitable for shiitake production, cover millions of acres throughout east and central Oklahoma. Currently, there exists only a few shiitake producers in Oklahoma who are experimenting with different strains and production methods.

## The Production Process

### Obtaining Suitable Logs

Selecting the best available tree species is the first step to successfully growing shiitake. Shiitake mushrooms have been reported to grow on red and white oaks, chestnut, ironwood or hornbeam, alder, aspen, poplar, cottonwood,

beech, birch, sweetgum, and pecan. There is general agreement that oaks work well, especially those in the white oak group. In Oklahoma, both white oak (*Quercus alba* L.), post oak (*Quercus stellata* Wangerh.) and sweet gum (*Liquidambar styraciflua* L.) represent the preferred species.

Logs should be cut from living trees free of any decay. Trees should be harvested during the dormant or winter season when the wood contains the maximum amount of stored carbohydrates. In Oklahoma, this would usually be from November to March. Log diameters should be from three to six inches while log lengths should be from three to five feet. During log cutting it is important not to damage the bark layer.

Log length is not a critical concern and should be determined mainly on the basis of the most manageable length. Log diameter is more critical. Logs smaller than three inches in diameter can dry out very quickly. Although smaller dimension logs will produce mushrooms more quickly, they will tend to decompose more rapidly. Logs greater than six inches in diameter can produce mushrooms over a longer period of time but require more inoculations to compensate for the greater diameter. They also may take longer to produce the first crop and have increased chances for becoming contaminated.

There have been many recommendations concerning log storage or curing. In general, if inoculation is not planned soon after making logs, then trees should be left tree length until shortly before inoculation. Traditional log curing has been from one to two months. However, many growers are cutting logs and inoculating as soon as possible to take advantage of the higher moisture content of trees immediately following felling. Generally, inoculation should occur within two weeks of felling a tree.

### Obtaining Shiitake Spawn

A mushroom is a reproductive structure of a fungus plant which produces spores. When a spore lands in a favorable environment, such as a log, it will germinate, sending thread-like filaments called hyphae into the log. The hyphae breaks down the log as it grows and after a period of time, usually at least six months, the fungus will begin to produce mushrooms. Spawn, which contains active hyphae, is the way shiitake producers introduce the fungus into the log.

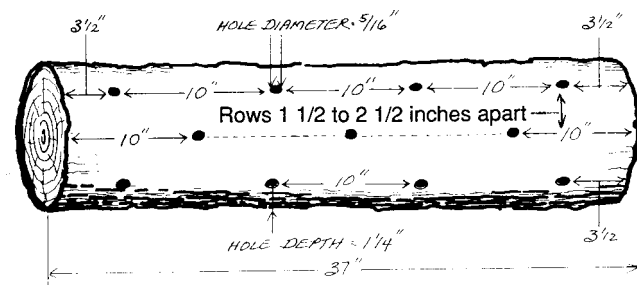
Spawn comes either as wooden plugs made from hardwood dowels or as sawdust. Many strains of shiitake are available and can be classified as cold weather, warm weather, or wide-range depending on when they produce mushrooms.

Most growers, unless they have some training in microbiology, purchase new spawn each time they inoculate logs. When ordering spawn, it is suggested that at least two strains of spawn be used. In Oklahoma, growers should consider a cold weather strain for growth in the spring or fall and a warm weather or wide-range strain for summer. Due to the lack of information, specific recommendations about strains for Oklahoma can not be made. Growers should experiment with several different strains of spawn from more than one supplier.

A new type of spawn called “comb spawn” has been developed in Japan but is not generally available in the United States. It is a wafer which has been cultured with spawn and inserted in a thin saw kerf in a log. It is reported to reduce the total time and labor needed for inoculation.

### Inoculation of Logs

Inoculation is placing the spawn into the logs so that the shiitake fungus can grow through the wood. Holes are usually drilled into the log, filled with spawn, and then covered with wax or other material to seal in moisture and protect against contamination. Holes for plug spawn should be 5/16 inch in diameter and 3/4 to 1 inch deep (Figure 1). Plugs are inserted into the logs and usually hammered flush with or just below the surface of the log. Sawdust spawn holes are generally wider and deeper being 3/8 inch in diameter and 1 1/4 inch deep. Sawdust spawn is packed by hand or by special injector into the drill holes. Better colonization by the sawdust spawn as compared to the plug spawn may reduce inoculations per log, but the sawdust spawn is more difficult to handle and you must be careful not to let the spawn dry out.



**Figure 1. One possible technique for preparing logs for inoculation**

Holes should be staggered evenly around the log. Rows running the length of the log are spaced 1 1/2 to 2 1/2 inches apart. The holes within a row should be spaced six to ten inches apart and alternating with the holes in the adjacent row. Heavier inoculation will accelerate the growth of the fungus within the log but also represents additional investment.

Other inoculation techniques include a variety of chain saw cuts. For short logs no more than two feet in length, a 1/2 inch thick wafer can be cut from each end of the log and a layer of sawdust spawn applied to the end. The cut wafer is then nailed back to the log. Another method is to space three to four chainsaw cuts, 1/3 of the way into the log, along each face of the log. The cuts are filled with spawn and sealed with melted paraffin. In combination with this method spawn can also be applied to the end of the log and covered with aluminum foil. Wedge cuts about 1 1/2 inches deep have also been used where spawn is applied to the cut and the wedge replaced and secured by thin plastic tape around the log.

### Incubation of Logs

Mushrooms will be produced after the shiitake fungus colonizes the log. The first “fruiting” will normally occur from six to eighteen months after inoculation and will depend on the strain, the inoculation rate, the incubation conditions and tree species. Monitoring and maintaining environmental conditions during the incubation period is a critical point in the production process.

During the first two months logs should be stacked closely to help maintain a high moisture content. Shiitake grows best when the moisture content of the wood is at least 35 to 45 percent. Growth becomes poor when the moisture content falls below 35 percent or rises above 60 percent. When the moisture content becomes low the log should be soaked or continuously watered for 48 hours. Following watering, good air circulation is needed to keep the surface of the logs dry to prevent contamination. The optimum situation is when the bark remains dry but the inside remains moist.

Shiitake spawn will grow between 40 and 90 degrees Fahrenheit but the optimum is 72 to 78 degrees Fahrenheit. Stacking logs under a canopy of trees or shade cloth which provides 60 to 70 percent shade helps to maintain moisture content while preventing the logs from becoming too warm. If the logs dry out or overheat the shiitake fungus can be killed. Common stacking methods include the X pattern and the crisscross pattern (Figure 2). On hill slopes the lean-to pattern can also be used effectively. Logs should be checked periodically and turned or restacked to keep the moisture content evenly distributed. Log moisture content can be monitored by including several logs of known dry weight and periodically weighing them to determine their moisture content.

### Mushroom Fruiting

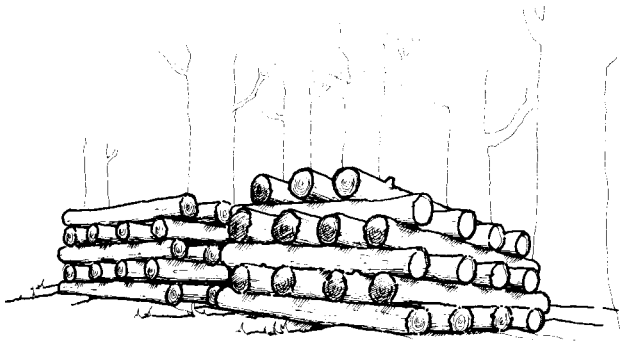
Natural fruiting of shiitake occurs under prolonged cool, moist conditions. It will usually occur within two weeks of a natural rainfall. Fruiting can be induced by soaking the logs in cool water for one to three days. Soaking time will vary depending on the difference between water and air temperatures. In general, the greater the temperature difference, the less soaking time is needed. Soaking temperatures will also vary by strain and growers should check with suppliers for details.

Traditionally, the logs will produce mushrooms in both the spring and the fall, although the fruiting period may be extended in the winter by placing the logs indoors. Many growers restack the logs during the fruiting period using the X pattern. The fruiting area should have slightly more light and air movement than the spawn-run area but still be protected from winds and direct sun. Once logs begin to fruit, they will normally produce mushrooms one to several times a year for up to six years.

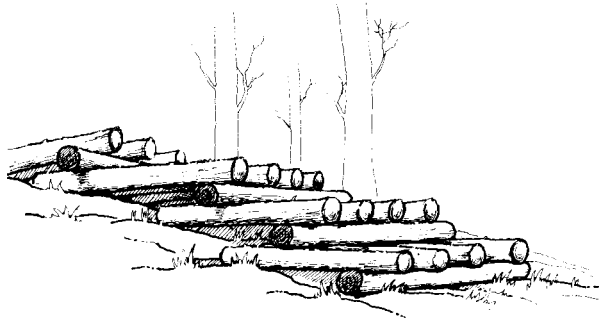
Shiitake can also be grown under greenhouse conditions. By controlling temperature and humidity conditions, logs can be forced to produce during the winter and summer when outside logs are not fruiting. These producers can take advantage of the best markets. Some experienced growers also grow shiitake on substrates other than logs. These include logs made from sawdust and other agricultural waste products such as wheat straw and corn stalks and cobs.

### Harvesting, Storage, and Marketing

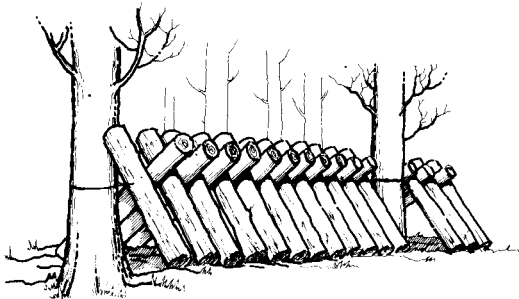
Mushrooms should be harvested on a daily basis, usually in the afternoon when the mushrooms are dry. Mushrooms are removed from the log by twisting or cutting at the base



Criss-Cross Method



Stacking Method on Slope or Hill



X Pattern Method

**Figure 2. Common stacking methods.**

when they have opened about 60 to 75 percent. They should be put immediately into cardboard boxes and refrigerated. Refrigeration can extend the shelf life of shiitake from four to five days to up to 2 or 3 weeks. Mushrooms should be shipped to market within 5 days of harvest but preferably sooner.

Mushrooms of lower quality or freshness can be dried, packaged and sold in retail and restaurant markets. Shiitake dry easily and reconstitute very well, so marketing by mail is also possible. Drying can be accomplished by placing the mushrooms over dry, warm air, preferably in sunlight which increases their vitamin D content. Under artificial drying, gentle heat of 90°F is gradually increased to 140°F over a 10 to 14 hour period. Seven pounds of fresh shiitake yields about one pound of dried mushrooms.

For most growers, direct, local marketing is probably the best marketing option. Many people are still unaware of this

mushroom as a new food option. In most cases, some education about the qualities of shiitake will be required. Marketing cooperatives may be a viable option in the future for smaller producers.

## Costs and Returns

Costs can vary greatly depending on raw material, equipment used, efficiency and costs of labor and practices implemented. Potential growers should also carefully consider the possible financial returns and risks in shiitake production. The following is an example of an outdoor operation in which 4,000 logs are inoculated each year (Baughman, 1989). However, growers are reminded that they should perform their own financial analyses to reflect their specific cash-flow situation. Assumptions for the following analyses are as follows. The scenario has a 15 year planning period for which inoculations cease in the twelfth year. Logs were assumed to fruit twice each year starting the year after inoculation. Over a four year period, a 16 percent loss in the number of logs inoculated is assumed (Table 1). Each log produces 3.06 pounds of mushrooms over the four year period.

A detailed description of assumptions for the cash-flow analysis is provided below. All cash flows were assumed to occur at the beginning of the year. The cash flow analysis (Table 2) is provided mainly for the reader to understand the components of an outdoor shiitake operation. Under the assumptions of the example, after-tax yearly net revenue becomes positive in year 3 of the operation, while after tax cumulative net revenue becomes positive in year 5. This reflects the up front equipment costs. Annual profit reaches a maximum in year 13 at \$43,279, while the total profit for the 15 year period is \$307,309. The reader is reminded that these figures change with any modification of assumptions.

## Operating Expenses

### Log covers:

- Plastic— .25 sq. ft./log @ \$0.018/sq. ft., 3 yr. life.
- Fabric— 1 sq. ft./log @ \$0.10/sq. ft., 4 yr. life.

### Tools/supplies:

- Sawdust spawn inoculation tool— 1/4000 logs inoculated @ \$22 ea.
- Staple gun— 1/12000 logs inoculated @ \$20. ea.
- Log drilling stands— 1/4000 logs inoculated @ \$17 ea.
- Electric drill—1/6000 logs inoculated @ \$210 ea.
- Drill bits—\$36/4000 logs inoculated.
- Electric extension cord— 1/8000 logs inoculated @ \$18 ea.
- Wax melting pot— 1/8000 logs inoculated @ \$40 ea.
- Wax baster— 1/4000 logs inoculated @ \$34 ea.
- Water hose & sprinkler head— 1/4000 logs on site @ \$35 ea., 4 yr. life.
- Scale for weighing logs— 60# capacity milk scale @ \$100.
- Picking & storage baskets for mushrooms— \$2/1000 lbs. mushrooms.
- Laying yard maintenance materials— 5% of original materials cost/yr.
- Steel racks for carrying and soaking logs— 1/25 logs soaked @ \$4 ea.
- Office supplies—cost estimated for small tools, paper products, telephone service.
- Tractor operation & maintenance— \$0.02/log on site/yr.

### Utilities:

- Outdoor operation— water & electricity @ \$0.14/log on site/yr.

**Advertising:**

\$0.30/lb. of mushrooms with expenses weighted to beginning of project. 33% of total expense occurring in first 3 years. Remaining expense spread evenly over next 12 years.

**Shipping:**

Packaging & labels— \$0.25/lb. of mushrooms.  
Transportation— \$0.50/lb. of mushrooms.

**Interest on borrowed money:** 11%/yr. based on cumulative net loss.

**Capital Expenses****Logs:**

Oak logs purchased @ \$0.50 ea., 6" diameter by 40" length.  
Spawn @ \$0.90/log.  
Wax @ \$0.03/log.  
Aluminum identification tags and staples @ \$0.05/log.

**Soak tank:**

Concrete vault, each log being soaked occupies 1.25 cu. ft., total capacity assumes logs to be fruited during one week are all soaked at same time, double capacity provided in case extra logs must be fruited to satisfy short term need.

**Laying yard:** (for laying and fruiting outdoors)

.8 sq. ft. ground space/log, shade cloth over top and on two sides @ \$0.20/sq. ft., wooden poles @ \$9 ea. and steel cables @ \$0.14/ft. hold up shade cloth, poles 12 feet apart on perimeter and approximately 24 feet apart on interior, perimeter poles held down by cable and buried deadman @ \$3.00 ea., cable clamps & thimbles @ \$0.70/set and screw eyes @ \$0.30 ea. fasten cables to poles and deadman, construction tools @ \$100.

**Tractor:**

Used farm tractor with front end lift @ \$5,000, 7 yr. life.  
Trailer for transporting logs @ \$500, 7 yr. life.

**Refrigerator:**

.41 cu. ft./lb. of mushrooms, holds all mushrooms fruited in one week.

**Scale for weighing mushrooms for sale:**

Electronic, digital readout @ \$595 ea., 6 to 7 year life.

**Revenue****Price:**

All mushrooms sold fresh.  
\$4.50/lb. of mushrooms produced.

**Advantages and Disadvantages****Advantages**

1. Shiitake can represent a supplemental income source to the landowner with low initial costs compared to other food enterprises.
2. Producing shiitake represents a way to utilize low quality hardwoods, an otherwise under-utilized resource. It can be integrated into conventional timber management practices.
3. The market for shiitake mushrooms is growing.

**Disadvantages**

1. Similar to other alternative enterprises, shiitake requires some time and effort to produce.
2. Production can be risky due to problems with low quality spawn, competing wood-rotting fungi, molds, termites, insects, and variable weather patterns.
3. The market for shiitake is not well developed and may require some education of the consumer. Price adjustments may be expected as more producers enter the marketplace.

**Conclusion**

Production of shiitake mushrooms represents a possible alternative enterprise for farmers and landowners in Oklahoma. As an alternative enterprise it has a high degree of risk. The future market is optimistic although any new producers will have to invest considerable time in developing the market. Very few yield studies have been completed in the United States but attempts to analyze the economics of shiitake production are optimistic about potential profits. Growers should begin on a small scale to experiment with different strains, inoculation techniques and incubation methods.

**Table 1. Outdoor production: Log losses and mushroom yields for 4000 logs on a four year cycle.**

| Year  | Logs                        |                           | Mushrooms       |                        |                |              |
|-------|-----------------------------|---------------------------|-----------------|------------------------|----------------|--------------|
|       | Number at Beginning of Year | Percent Loss <sup>1</sup> | Number Fruiting | Percent of Total Yield | Pounds Per Log | Total Pounds |
| 1     | 4000                        | 10                        | 0               | 0                      | 0.00           | 0            |
| 2     | 3600                        | 3                         | 3600            | 18                     | .54            | 1944         |
| 3     | 3492                        | 3                         | 3492            | 47                     | 1.44           | 5028         |
| 4     | 3387                        | 0                         | 3387            | 35                     | 1.08           | 3658         |
| Total |                             | 16                        |                 | 100                    | 3.06           | 10630        |

<sup>1</sup> Loss is assumed to occur at end of year.

**Table 2. Cash flow for outdoor shiitake production.**

| ITEM                       | 1      | 2      | 3      | 4     | 5     | 6     | 7      | 8      | 9      | 10     | 11     | 12     | 13     | 14     | 15     |
|----------------------------|--------|--------|--------|-------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Costs: <sup>1</sup>        |        |        |        |       |       |       |        |        |        |        |        |        |        |        |        |
| Tools/supply               | 1390   | 1017   | 980    | 1508  | 1613  | 1352  | 1770   | 1817   | 1600   | 1909   | 2041   | 1710   | 751    | 654    | 542    |
| Utilities                  | 560    | 1107   | 1680   | 2280  | 2371  | 2466  | 2565   | 2667   | 2774   | 2885   | 3000   | 3120   | 2349   | 1603   | 821    |
| Advertising                | 4252   | 4422   | 4599   | 2393  | 2488  | 2588  | 2591   | 2799   | 2911   | 3027   | 3148   | 3274   | 3405   | 3542   | 3683   |
| Shipping                   | 0      | 1516   | 5656   | 8969  | 9327  | 9700  | 10088  | 10492  | 10912  | 11348  | 11802  | 12274  | 12765  | 10848  | 4752   |
| Interest                   | 2474   | 4013   | 2657   | 0     | 0     | 0     | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      |
| Logs                       | 5920   | 6157   | 6403   | 6659  | 6926  | 7203  | 7491   | 7790   | 8102   | 8426   | 8763   | 9114   | 0      | 0      | 0      |
| Soak tank                  | 3145   | 0      | 0      | 0     | 0     | 0     | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      |
| Laying yard                | 1726   | 0      | 1867   | 0     | 0     | 0     | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      |
| Tractor                    | 5500   | 0      | 0      | 0     | 0     | 0     | 0      | 0      | 72380  | 0      | 0      | 0      | 0      | 0      | 0      |
| Refrigerator               | 0      | 6850   | 0      | 0     | 0     | 0     | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      |
| Scale                      | 0      | 619    | 0      | 0     | 0     | 0     | 0      | 7830   | 0      | 0      | 0      | 0      | 0      | 0      | 0      |
| Revenue                    | 0      | 9098   | 33934  | 53808 | 55960 | 53199 | 60527  | 62948  | 65465  | 68084  | 70807  | 73640  | 76585  | 65083  | 28505  |
| Before Taxes: <sup>1</sup> |        |        |        |       |       |       |        |        |        |        |        |        |        |        |        |
| PERIOD NET REVS.           | -24967 | -16604 | 10092  | 31999 | 33235 | 34890 | 35921  | 29361  | 39167  | 40489  | 42052  | 44147  | 57315  | 48435  | 18707  |
| CUM NET REVENUE            | -24967 | -41571 | -31478 | 521   | 33755 | 68645 | 104566 | 133928 | 17395  | 213584 | 255636 | 299783 | 357098 | 405533 | 424241 |
| After Taxes: <sup>2</sup>  |        |        |        |       |       |       |        |        |        |        |        |        |        |        |        |
| PERIOD NET REVS.           | -21570 | -13390 | 7769   | 23976 | 24626 | 25730 | 26474  | 19681  | 28953  | 29608  | 30694  | 32021  | 43279  | 35741  | 13817  |
| CUM NET REVENUE            | -21570 | -24960 | -27191 | -3214 | 21411 | 47141 | 73615  | 93296  | 122250 | 151857 | 182451 | 214472 | 257751 | 293492 | 307309 |

<sup>1</sup> All values are in dollars inflated at 4 percent to year of occurrence, before taxes. Columns may not add due to rounding error.

<sup>2</sup> All values are in dollars inflated at 4 percent of occurrence, after taxes. Columns may not add due to rounding error.

## References

- Arkansas Cooperative Extension. 1986. Shiitake mushroom production in Arkansas. G.L. Klingaman. ed. Cooperative Extension Service. University of Arkansas. Fayetteville, AR. 36 pgs.
- Baughman, M.J. 1989. Financial Analysis of shiitake mushroom production. In Shiitake Mushrooms: the proceedings of a national symposium and trade show. University of Minnesota. St. Paul, Minnesota. pg. 169-179.
- Burnett, Christopher. 1988. Shiitake mushroom production: good food combines good forestry and good economics. In Illinois Forest Management. Cooperative Extension Service. Univ. of Illinois. Urbana, Illinois. Vol. 2 (15) pg. 1-4.
- Cotter, Van T. and Tim Flynn. 1986. An easy, inexpensive cultivation method. Mushroom-The Journal of Wild Mushrooming. Vol. 13(4). pg. 35-36.
- Harris, Bob. 1986. Growing Shiitake Commercially. Science Tech Publishers. Madison, Wisconsin. 72 pgs.
- Hill, Deborah B. 1987. Growing the "forest" mushroom. In Natural Resource Newsletter. College of Agriculture. University of Kentucky, Lexington, Kentucky. Vol. 6(3) pg. 1-3.
- Leatham, Gary F. 1982. Cultivation of shiitake, the Japanese forest mushroom, on logs; a potential industry for the United States. Forest Products Journal, Vol 32(8). pg. 29-35.
- Royse, Daniel J., L.C. Schisler and D.A. Diehle. 1985. Shiitake Mushrooms: consumption, production and cultivation. Interdisciplinary Science Reviews. Vol. 10(4). pg. 329-335.
- Tahei Fujimoto. 1988. High speed year-round shiitake cultivation. Shiitake News Vol. 5(2). pg. 108.
- University of Illinois Ag. Communications. 1988. Economic opportunities could mushroom in Illinois forests. National Woodlands. Vol. 11(3) pg. 5-6

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# Growing Mushrooms Commercially — Risks and Opportunities



Danny L. Barney

People have harvested mushrooms from the wild for thousands of years for food and medicines. Of the estimated 1.5 million species of fungi, about 10,000 produce the fruiting bodies we call mushrooms. While commercial harvesting of wild mushrooms continues today, most of the world's supply comes from commercial mushroom growers. The Chinese first cultivated shiitake (*Lentinula edodes*) mushrooms around 1100 AD, with domestication efforts beginning centuries earlier. White button mushrooms (*Agaricus* spp.), most familiar to Americans and Europeans, were first domesticated in France in 1650. Commercial production began in the United States in the 1880s. *Agaricus* is the leading mushroom crop worldwide and accounted for 99 percent of the 1997 United States' mushroom production. Oyster mushrooms (*Pleurotus* spp.) were more recently domesticated, and now rank second in world production. Shiitake mushrooms, which are very popular in Asian cultures, rank third. Many other edible mushrooms, such as straw and wood ear mushrooms, are gaining in popularity.

Roughly 300 mushroom species are edible, but only 30 have been domesticated and 10 are grown commercially. Button, oyster, and shiitake mushrooms make up about 70 percent of the world's production (table 1). During the past 30 years, mushroom production worldwide increased

twenty-fold, with much of that increase occurring in the 1980s and 1990s. Increased demand for specialty mushrooms (everything besides *Agaricus*) has been particularly strong. Asian countries continue to dominate world production and consumption, however, consumption in the United States has increased sharply in recent years, providing potential opportunities for mushroom growers.

Mushroom production in the United States has traditionally centered in Pennsylvania, which produces nearly half the nation's button mushrooms. California and Florida are the second and third leading producers, with limited production in 27 other states. Large-scale growers with established, year-round markets dominate commercial mushroom production. In 1997, 7 percent of United States mushroom farms supplied 20 million pounds or more each, or 38 percent of total U.S. production. In contrast, 36 percent of mushroom farms produced less than one million pounds per year.

Even established growers are challenged with recent imports of canned *Agaricus* from China, Chile, India, and Indonesia. In the face of this competition, the prospects for new *Agaricus* growers are poor. The number of button mushroom growers in the United States has decreased steadily, from 357 in 1987 to 153 in 1997.

Table 1. World production of cultivated edible mushrooms in 1986 and 1994.

| Species                                      | Fresh weight and percentage of total production |      |                |      | Percent increase |
|--|---|------|----------------|------|------------------|
|  | 1986  |      | 1994           |      |                  |
|  | (X 1,000 tons)                                  | (%)  | (X 1,000 tons) | (%)  | (%)              |
| <i>Agaricus bisporus</i><br>(button)         | 1,215   | 55.8 | 1,846          | 37.6 | 51.9             |
| <i>Lentinula edodes</i><br>(shiitake)        | 320   | 14.7 | 826            | 16.8 | 158.1            |
| <i>Pleurotus species</i><br>(oyster)         | 169   | 7.8  | 797            | 16.3 | 371.6            |
| <i>Auricularia species</i><br>(wood ear)     | 119   | 5.5  | 420            | 8.5  | 301.0            |
| <i>Volvariella volvacea</i><br>(straw)       | 178   | 8.2  | 299            | 6.1  | 68.0             |
| <i>Flammulina velutipes</i><br>(enokitake)   | 100   | 4.6  | 230            | 4.7  | 130.0            |
| <i>Tremella fuciformis</i><br>(jelly fungus) | 40  | 1.8  | 156            | 3.2  | 290.0            |
| <i>Hypsizygus marmoreus</i><br>(bunashimeji) | ---   | ---  | 55             | 1.1  | ---              |
| <i>Pholiota nameko</i>                       | 25  | 1.1  | 27             | 0.6  | 8.0              |
| <i>Grifola frondosa</i> (maitaki)            | ---   | ---  | 14             | 0.3  | ---              |
| Others                                       | 10  | 0.5  | 239            | 4.8  | 2,290.0          |

Table 1 adapted from S.T. Chang, 1996. Mushroom research and development - equality and mutual benefit. *Mush. Biol. Mush. Prod.* Vol. 2:1-10.

Specialty mushroom production is more evenly distributed throughout the United States than is button mushroom production. The number of commercial specialty mushroom growers in the United States decreased slightly (from 188 to 183) between 1995 and 1997. There are a few large-scale specialty mushroom farms. Most growers operate small farms and focus on local markets. For 1997, the average specialty mushroom farm in the United States produced approximately 52,000 pounds of mushrooms with gross

sales of about \$150,000. United States production of oyster and shiitake mushrooms appears in Figure 1.

Shiitake and oyster mushrooms are the best-known specialty mushrooms, and probably the easiest to market. *Auricularia* spp. (wood ear), *Volvariella volvacea* (straw mushroom), *Flammulina velutipes* (enokitake), *Grifola frondosa* (maitake), and *Tremella fuciformis* (white jelly or fungus ear) are also increasing in popularity. *Volvariella volvacea* (straw) mushrooms are

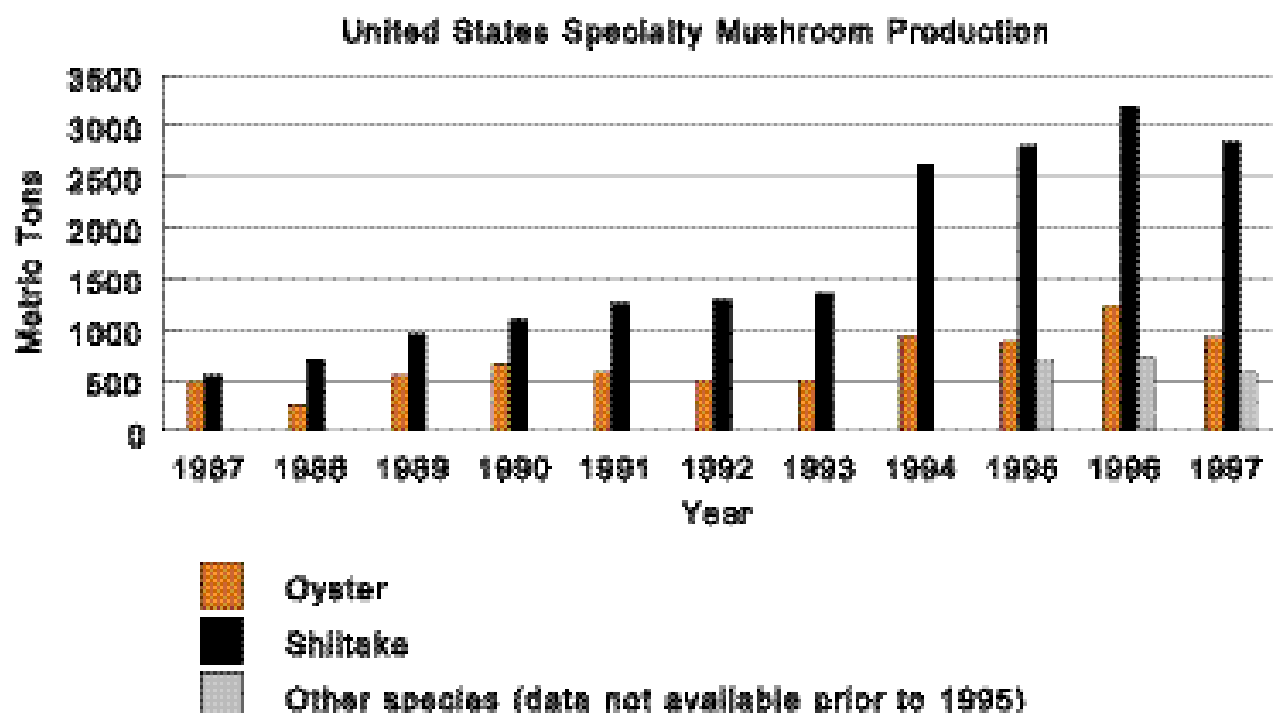


Figure 1. United States specialty mushroom production for 1987-1995. Data provided by the United States Department of Agriculture National Agricultural Statistics Service.

the easiest to grow, produce mushrooms in as little as 4 days, and are adapted to areas with high temperatures. They are not as popular with consumers as button, oyster, or shiitake mushrooms, but still account for 6 percent of the world's production. *Ganoderma lucidum* (reishi), *Hericium erinaceus*, and *Hypsizygus marmoreus* (bunashimeji) are medicinal mushrooms used primarily in Asia. Medicinal mushrooms require specialized marketing in the United States.

## Production facilities

Mushrooms lend themselves to many different growing systems from simple and inexpensive to highly sophisticated and expensive. This publication was written only to provide an overview of opportunities and risks for potential mushroom growers. Sources providing detailed, how-to cultural information are listed at the end of this bulletin. Much information on state-of-the art

mushroom production and marketing may also be found on the Internet. Be aware that some production techniques are patented and require payments to patent holders if they are used.

Shiitake has long been grown on sections of logs about 3ft in length. Oak is the preferred species, although beech, chestnut, and other hardwoods have been used in the United States. Gambel or scrub oak (*Quercus gambelii*) is found in parts of the Intermountain West and can be used for shiitake production. Other oak species suitable for growing shiitake are native to Oregon and California. For outdoor production, log sections are inoculated with spawn (a starter mix of fungal mycelium and sawdust or grain) and set aside to allow the fungi to develop. Shade cloth is often used to protect logs stored outdoors from excessive drying caused by direct sunlight. The development period is called the spawn run and can last 6 to 18 months, depending on the log

species, diameter, moisture, and temperature. At the end of the spawn run, the logs are transferred to a cool, moist raising yard where the mushrooms develop and are harvested. In outdoor systems, most shiitake production occurs in the spring and fall. Greenhouses and converted farm buildings are used to produce winter crops. A single log may bear five crops of mushrooms. Some other mushroom species can also be grown in basic, nonmechanical facilities.

Much of the increase in mushroom production is due to the development of high-yield systems that depend on precise environmental controls. In 1988, shiitake production in the United States was equally divided between natural logs and synthetic logs made from sawdust, straw, corncobs, and various amendments. Eight years later, synthetic log production doubled and now makes up more than 80 percent of the total. By using synthetic logs, growers can harvest shiitake mushrooms year-round and produce three to four times the yield in one tenth the time natural logs require.

High yields and rapid production cycles with most mushroom species require specialized facilities. Substrates (materials the mushrooms grow in) are blended and packaged into special plastic bags or jars. Typical substrates include sawdust, grain, straw, corn cobs, bagasse, chaff, and other agricultural byproducts. Containers and substrate are then either pasteurized or sterilized to remove contaminating microorganisms. Hot water baths can be used for pasteurization, but sterilization may require a commercial steam sterilizer. Some growers compost substrates outdoors and then sterilize them inside heated sheds.

After being pasteurized or sterilized, the substrate-filled containers are inoculated with the desired fungi and placed into spawn run rooms where temperature, humidity, light, and sometimes atmospheric gases are carefully controlled. When the spawn run is complete, the substrate may need additional treatments before mush-

rooms develop. Many mushroom species require changes in temperature, moisture, substrate, and/or light to begin fruiting. Large-scale, highly technical facilities are expensive to construct and operate. Whether you use a basic or sophisticated production system, growing mushrooms is labor intensive.

A third option for mushroom production is to harvest mushrooms from the wild. In the Pacific Northwest, large quantities of morel, chanterelle, matsutake, and bolete mushrooms are harvested each year. Offsetting the advantage of no production facilities are high labor costs, unpredictable crops, inclement weather, and increased transportation. Although researchers have made progress in domesticating morel mushrooms, most are still harvested from the wild. To learn more about wild mushroom harvests, refer to the *For more information* section later in this publication.



## Management

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Commercial mushroom production requires high levels of management input and skill. A common mistake new growers make is to believe that growing mushrooms is easy. Each species requires specialized treatment to produce consistent yields of high-quality, marketable mushrooms. Another common mistake is to start too large and diversify too soon. As mentioned earlier, mushroom growing is labor intensive. It is easy to quickly become overwhelmed with the physical requirements of mixing and sterilizing substrates, ordering and inoculating with spawn, maintaining environmental controls, harvesting and processing mushrooms, marketing, business management, and many other tasks that go with a commercial enterprise.

Trying to learn a single crop is difficult enough, and mastering several different mushroom crops at once may be impossible. Some spawn suppliers offer starter kits and instructions. Using small starter kits will allow you to gain some experience with different mushroom crops with minimum investments in time and money. Keep detailed production and financial records to evaluate which crops show commercial promise.

As with any other crop species, not all mushrooms are created equal. Different strains or lines of shiitake, for example, vary in color, size, shape, firmness, cultural requirements, and yields.

Only the largest mushroom growers produce their own spawn. Spawn culture is highly technical and requires specialized facilities and equipment. Most growers rely on companies that specialize in producing high-quality spawn for their culture material.

If you are not already experienced in mushroom production, start small and expand slowly. Take time to learn all you can about growing and selling

mushrooms while you gain some practical experience. Study the market and decide which types of mushroom crops and production systems would be enjoyable, feasible, and profitable for you. Join growers' organizations and subscribe to newsletters about mushrooms. Universities sponsor conferences and workshops on specialty farming in general and mushroom farming in particular.

## Marketing

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The greatest challenge all specialty farmers face is marketing. Deciding what to grow, where and how to grow it, who makes up the target market, and how to package and advertise are just a few of the things that go into marketing. A thorough study of mushroom production and marketing is imperative before buying equipment and starting even a small-scale operation.

The demand for specialty mushrooms is huge, particularly in Asian countries. Trying to market internationally, however, is beyond the resources of most small and medium-sized companies. China produces nearly 1.5 billion pounds and Japan more than 300 million pounds of shiitake each year. Likewise, national markets in the United States are dominated by large companies and produce brokers. Most small-scale mushroom farmers in the United States focus on local markets. Specialty mushrooms are best known and most widely used among certain Asian cultures, and local sales may be best in areas with large populations of Asian-Americans. Mushrooms are sold fresh, dried, or processed. According to the U.S. Department of Agriculture, most specialty mushrooms grown in the United States are sold fresh.

For wholesale, consider locally-owned or operated groceries, restaurants, and health food stores. You can make direct sales to customers through farmers markets, subscriptions, and on-farm sales. Forming a cooperative with other growers in your area can improve marketing by increasing quantities and variety. Particularly for dried or processed mushrooms, you might con-





sider selling direct to consumers through mail order or the Internet. Whatever your marketing strategy, remember that quality and grading are critical in producing and selling mushrooms. Before deciding on any market strategy, thoroughly explore local, state, and federal regulations that will affect your growing, processing, and shipping.

## Opportunities and risks

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Mushrooms offer small-scale growers several advantages. Growing facilities range from logs stacked outdoors under a shade cloth to sophisticated production chambers with precisely controlled temperatures, humidity, and light. Specialty mushrooms are high value crops, typically selling at wholesale prices of \$3 to \$6 per pound. Depending on the production system, you can grow large quantities in a small space.

Mushrooms can be delicious and are rich in proteins, vitamins, and minerals while containing little fat. Demand for exotic culinary mushrooms has greatly increased in recent years and shows no sign of slowing. Certain mushroom species reportedly provide health benefits, including anti-cancer and anti-viral properties and the potential to reduce cholesterol and the risk of heart disease. With alternative medicine becoming more widely accepted, opportunities for health foods and dietary supplements should continue to increase.

Researchers have developed methods of effectively and economically producing many species of edible mushrooms. These production

systems use agricultural waste products, including straw, chaff, sugar beets, corncobs, waste paper, sawdust, coffee grounds, livestock manure, slaughterhouse wastes, and other materials. Once the substrate has been broken down during mushroom production, it can be sold for organic fertilizers and compost.

With opportunities, however, come risks. If you grow mushrooms outdoors, weather is an important consideration. Mushrooms are strongly affected by temperature, humidity, and light. A cold snap, heat wave, or drought can reduce yields or favor the development of undesirable “weed molds.” Outdoor production also generally provides lower yields and longer production times than are available with indoor facilities. Outdoor-grown mushrooms also fruit seasonally, producing crops when supplies are greatest and prices are lowest. People are not the only ones who enjoy fresh mushrooms. Insects and animal pests can become serious pests for mushroom farmers, especially with outdoor operations.

Indoor growers also face challenges. Precision-controlled indoor facilities are expensive to build, operate, and maintain. Operating and maintaining environmental controls require a certain degree of technical expertise. Cleanliness is critical in controlled environment production systems to ensure high-quality products free of potentially toxic contaminants. Pest control is also critical because some insect pests, such as fungus gnats, flourish under the same conditions that favor mushrooms. With high yields and short production cycles, harvest windows are short.

Whether you grow mushrooms indoors or out, labor should be a serious concern. Mushroom production is labor intensive. Before expanding beyond a small operation that you can maintain yourself, ensure that you have a consistent supply of laborers willing to work for you at competitive wages. Be prepared to provide training for your workers. Know and comply with worker protection regulations.

While demand for specialty mushrooms has increased greatly in recent years, so has production. Between 1986 and 1994, worldwide production of shiitake mushrooms increased 158 percent and oyster mushrooms by 371 percent. At the same time, the prices growers received dropped. For United States' shiitake growers, prices decreased from \$5.42 per pound in 1986 to \$3.09 per pound in 1997. From 1995 through 1997, wholesale prices for oyster mushrooms decreased from \$2.49 to \$1.90 per pound. Only increased yields and shortened production cycles have kept growers profitable. Oyster and shiitake mushroom production in the United States peaked in 1996 and decreased in 1997 (figure 1).

The development of improved production methods and increased demand has motivated large companies around the world to start growing mushrooms. Increased competition means that growers must carefully consider and manage marketing. Be prepared for market slumps caused by overproduction. Good practices include having backup plans in place for selling to alternative markets or preserving and storing your mushrooms for later sales.

Another challenge growers face is liability. Oyster mushrooms, for example, produce spores that cause allergic reactions in some people. Provide the appropriate safety equipment for your workers, including masks or respirators to protect them from fungal spores. Know what to do if an employee experiences an allergic reaction. Perhaps a greater concern is the risk of being sued by a consumer who becomes ill and accuses you of selling contaminated produce. Agricultural waste products used for substrates sometimes contain

pesticides, medicinal residues, and other chemicals that can be concentrated during recycling. They may also contain toxic microorganisms, such as aflatoxin. You can reduce liability risks by ensuring your substrates are free of pesticides and other toxins; using only high-quality, commercially-grown spawn; and maintaining hygienic conditions and excellent production records. Liability insurance would also be advised.

Be cautious about claims of medicinal and health-related properties. While mushrooms have long been used as medicines and health foods, supporting scientific evidence for their use is often sketchy, at best. In selecting mushroom crops, stay with those proven safe for human consumption. Don't experiment! Remember that some fungi produce deadly toxins. Safe and effective research on the effects mushrooms have on humans requires highly specialized training and facilities, and is closely regulated by health agencies. Avoid unsupported health claims in your marketing. Ensure that you meet or exceed local, state, and federal laws regarding production and marketing of food products. Products marketed as medicinal must meet United States Food and Drug Administration regulations.

## In conclusion

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Specialty mushrooms offer small-scale growers opportunities, however, there are risks. Do your homework before investing in land or production facilities. Read several books by different authors to get a balanced view of mushroom farming. Treat claims of quick and easy profits with great skepticism. Visit several mushroom growers outside your area to gain a grower's-eye-view of what it is like to produce and market mushrooms. Join mushroom growers' organizations and attend conferences and workshops. Calculate your costs for starting and operating a mushroom farm, including labor costs. Determine break-even points and the time you will need to recapture your investment. Be conservative in estimating yields, sales, and profits. Plan on supporting your mushroom operation with savings or off-farm

work until you pass the break-even point. In short, give yourself every chance for success.

## For more information

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### Extension publications

The University of Idaho has many pamphlets, video tapes, and software packages on establishing and operating agricultural enterprises. To order publications or a catalog, contact Agricultural Publications, University of Idaho, Moscow, ID 83844-2240. The Internet address is <http://info.ag.uidaho.edu>. Publications of particular interest include:

Forming a cooperative. CIS 840.

Business and the family. CIS 940.

Licenses and legal requirements. CIS 941.

Conduct your own garden research. CIS 1041.

Marketing your produce directly to consumers. EXT 742.

Specialty farming in Idaho: Is it for me? EXT 743.

Specialty farming in Idaho: Selecting a site. EXT 744.

Special Forest Products. CIS 952.

Cultivation of Shiitake on Natural and Synthetic Logs. 1997. D. Royse. Order by contacting the Publications Distribution Center, Pennsylvania State University, 112 Agricultural Administration Building, University Park, PA 16802. Phone: 814-865-6713.

### Government publications

The USDA Forest Service has many publications on harvesting special forest products, including mushrooms. Many of these publications can be downloaded from the Internet or ordered from on-line catalogs. An excellent starting point is: USDA Forest Service Pacific Northwest Research Station, P.O. Box 3890, Portland, Oregon 97208-

3440, phone: (503) 808-2592. [Http://www.fs.fed.us/pnw/](http://www.fs.fed.us/pnw/).

Two publications of particular interest from the PNW Research Station are:

Molina, R., et al. 1993. *Biology, Ecology, and Social Aspects of Wild Edible Mushrooms in the Forests of the Pacific Northwest: A Preface to Managing Commercial Harvest*. PNW-GTR-309.  
Hosford, D. et al. 1997. *Biology and Management of the Commercially Harvested American Matsutake Mushroom*. PNW-GTR-412.

### Books

Many books are available on growing and using mushrooms. For a detailed list consult *Books in Print* at your library or bookstore. Some examples include:

*Przybylowicz, P. and Donoghue, J. 1989. Shiitake Growers Handbook. Kendall/Hunt Pub. Co., Dubuque, IA.*

*Stamets, P. 1993. Growing Gourmet and Medicinal Mushrooms. Ten Speed Press, Berkeley, CA.*

*Weber, N. 1995. A Morel Hunter's Companion. Thunder Bay Press, Lansing, MI.*

### Journal articles

*Royse, D. 1997. Specialty Mushrooms and Their Cultivation. Horticultural Reviews, Volume 19, pp 59-97. ISBN 0-471-16529-8.*

### Internet

The Internet provides access to hundreds of sources of information on mushroom cultivation and use.

## About the author

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## Growing Shiitake Mushrooms in an Agroforestry Practice

by **Johann Bruhn, Ph.D.**, Research Associate Professor, Division of Plant Sciences, University of Missouri-Columbia, & **Michelle Hall**, Senior Information Specialist, Center for Agroforestry, University of Missouri-Columbia

### Cultivating Shiitake Mushrooms through Forest Farming

Cultivating shiitake mushrooms represents an opportunity to utilize healthy low-grade and small-diameter trees thinned from woodlots as well as healthy branch-wood cut from the tops of harvested saw-timber trees. When the mushrooms are collected and marketed, the result is a relatively short-term payback for long-term management of wooded areas.



The cultivation of shiitake mushrooms on solid wood requires a significant amount of shade and wind protection, but not a significant amount of acreage. Therefore it is an excellent opportunity for landowners with smaller acreages to utilize forested or shaded areas. Shiitake producers can often obtain wood for cultivation from land

“When I walk into a restaurant and see my mushrooms on the menu, it gives me huge pleasure and makes all the work worthwhile.”

– Nicola McPherson, Ozark Forest Mushrooms



management agencies or private landowners. In addition to making productive use of woodlots and forested acres, logs that have been used for shiitake production, called “spent” logs, can be ground and recycled as compost (see page 12 for *Kimmons and others, 2003*) or used as a fuel and heat source for winter mushroom production (see box page 6).

Shiitake mushrooms can be grown indoors or outdoors on almost any deciduous wood that retains its bark for a number of years. When shiitake are cultivated outdoors on logs in a managed shade environment, a forest farming practice is initiated.

The practice of intentionally managing shade levels in a forest to favor the production of certain crops represents the agroforestry practice called forest farming. Properly applied, forest farming can enhance and diversify income opportunities, while at the same time improving the composition and structure of the forest for long-term stand health, quality and economic value. By developing an understanding of the interactions between the overstory trees and the understory environment, forest management activities can be used to create understory sites ideal for growing profitable shade-loving crops like shiitake mushrooms. The shade-loving plants that may be grown in the





*In this forest farming practice, shiitake and other forest farming products, such as ferns and ginseng, are grown under the shade of trees.*

understory of a forest are often termed non-timber forest products. However, to accomplish this, forest canopy densities must be controlled.

### **Getting Started: Basic Steps for Shiitake Production**

- 1) Understanding the Shiitake Life Cycle
- 2) Selecting and Preparing a Shiitake Cultivation Site
- 3) Obtaining Substrate Logs
- 4) Thinning as a Tool for Shiitake Cultivation
- 5) Shiitake Strain Selection
- 6) The Inoculation Process
- 7) Spawn Run
- 8) Fruiting the Crop
- 9) Harvesting
- 9) Pest Management
- 10) Shiitake: An Emerging Market

### **Understanding the Shiitake Life Cycle**

Although specialty mushroom production in a forest farming practice is intriguing, it should not be considered “quick and easy.” To establish a successful production system, a great deal of knowledge and planning is necessary. Before beginning to cultivate shiitake mushrooms, it is important to understand the shiitake life cycle and how the forest farming relationship interacts with this cycle.

Fungi do not use photosynthesis to produce their own food. Many mushroom fungi (including shiitake) obtain energy and nutrients by decomposing dead plant material. Shiitake decay the cellulose and lignin of wood. The visible part of the shiitake fungus that is harvested and consumed is the fruiting body (mushroom), connected to an unseen mycelium consisting of tiny threads growing in the log substrate. The mycelium derives nutrients by decaying inoculated logs, and a portion of these nutrients is eventually used to produce mushrooms.

Mushrooms are often called fruiting bodies because they are the site of spore production by the fungus. The mushroom stem serves to elevate the mushroom cap into the air; the cap serves to protect the developing gills; and the gills provide an extensive surface on which myriad spores are produced. Mushroom spores are sexual propagules of the fungus species, and therefore are highly variable. This is why we do not use spores as inoculum to cultivate shiitake. The mycelium and mushrooms produced from spores would likely differ from the parent strain in various important characteristics.



*Above: The mycelium is often visible at the ends of logs after spawn run. The rows of inoculation holes were spaced too far apart in the log above to effect complete colonization. As a result, undesirable colonization by competing decay fungi may result. (See box page 5.) Inset: Inoculated and fully colonized logs at the fruiting stage.*



### **Selecting and Preparing a Shiitake Cultivation Site**

One of the keys to successfully growing shiitake mushrooms in the forest is to select or produce a cultivation site with an overstory canopy that provides the appropriate amount of shade.

In the initial process of selecting a shiitake cultivation site, realize that north- to east-facing slopes will help protect against sun and heat. Ravines and valleys often provide access to water as well as superior shade.

Shade levels can be adjusted by manipulating the structure and/or species composition of the forest. If there is not enough shade for the understory crop, more trees can be planted or retained to produce more shade. Wind protection and shade can also be enhanced by hanging a curtain of mesh shade fabric

### **Materials Checklist:** **Outdoor Log Cultivation of Shiitake**

- Access to water for forced fruiting. (Cooler water is better.)
- A cultivation area with shade and protection from wind.
- Hardwood logs cut from healthy pole-sized trees, or from healthy branches of larger trees.
- Extremely high-speed drill (available from professional suppliers). A 10,000 RPM works very well for this purpose. If you purchase only one piece of equipment, it should be an extremely high-speed drill.
- Screw-tip drill bits with adjustable collar stops.
- Spawn and spawn-plunging tool.
- Cheese wax: For sealing sawdust or dowel spawn.
- Daubers: For applying cheese wax.
- Spawn and supplies can be purchased from professional suppliers, such as Field and Forest Products, Inc. – see page 11.

around the edges of the cultivation site. If there is too much shade, the stand can be thinned or individual trees can be pruned. Over time, the changes that occur in a mature or developing stand may require that both thinnings and new tree establishment be applied to maintain the required level of shade and wind protection. Evergreen species provide the most useful spring and autumn shade, but an overstory of sugar maple or oak will provide earlier and later season shade than cherry, walnut or honey locust. A good way to judge the adequacy of shade and wind protection in the cultivation area is based on mushroom condition. Under excessive shade, mushrooms produce longer stems and smaller caps. A 1- to 2-inch stem is ideal. If protection is inadequate, developing mushrooms may suffer from exposure and dehydration.

### **Obtaining Substrate Logs**

Log-grown shiitake are better quality and can have a longer shelf life than shiitake grown on supplemented sawdust substrates (a common large-scale indoor method). Log-grown shiitake also achieve higher prices in some segments of the wholesale and retail markets, especially if they can be certified local or organic.

Shiitake logs can be obtained both from the stems of healthy young trees selected for thinning and from healthy branch-wood taken from the tops of trees felled for saw-timber. In either case, only logs with intact bark, free of heartrot, and with as much sapwood as possible, should be selected. Logs already dead or with heartrot will be infected with other decay fungi and must be avoided. If you do not have access to forested areas, purchase logs from a public land management agency or a contract logger. If you contract for logs, be sure to specify undamaged bark and appropriate diameter.

The ideal time to fell trees is mid- to late-winter, for early spring inoculation. This is especially true for sugar maple, which begins sap flow earlier than oaks. For spring inoculation, it is best to harvest trees in February for inoculation in April or early May. Felled logs should be protected from desiccation (wind and sun) to maintain an internal moisture content above 35 percent.

While it is desirable to inoculate logs for shiitake production in the very early spring, some large-scale growers need to inoculate a portion of their crop of logs during the early winter. If this is necessary, it is important not to harvest trees for substrate logs until they have achieved complete dormancy. Trees harvested before they are completely dormant will not have finished storing carbohydrate in the sapwood, and therefore will contain less energy for mycelial growth and mushroom production.

At the University of Missouri's Horticulture and Agroforestry Research Center, sugar maple and white oak have proven to be superior substrate species. Other dense hardwoods with good bark retention can also be used to produce shiitake. Pines and other conifers are not effective hosts for shiitake production.

Properly managed, smaller logs (3" to 5" diameter at the smaller end and 36" long) produce more mushrooms per unit of log weight and are consumed more quickly than larger diameter logs. This is partly because larger logs (especially oaks) tend to contain more decay-resistant heartwood. Also, the bark on larger logs begins to deteriorate before the entire wood volume can be exploited by the shiitake. Also keep in mind that larger logs are heavier, and logs need to be moved at least several times in preparation for their service as shiitake substrate.

## Thinning as a Tool for Shiitake Cultivation

Keep in mind that the area to be managed as the actual mushroom production site is relatively small compared to the forest area required to produce a sustainable supply of substrate logs.

Before thinning a forest area, careful thought and planning is required. To maximize forest health, timber, wildlife and/or aesthetic values, talk to resource professionals at the Missouri Department of Conservation (<http://mdc.mo.gov/>), Natural Resources Conservation Service ([www.nrcs.usda.gov/](http://www.nrcs.usda.gov/)) or the Missouri Consulting Foresters Association ([www.missouriforesters.com](http://www.missouriforesters.com)). Also, visit the Missouri Timber Price Trends Report online at [www.mdc.mo.gov/forest/products/prices/](http://www.mdc.mo.gov/forest/products/prices/) for tree values, to avoid unnecessarily removing a potentially high-value species. Traditionally, black walnut, white oak and red oak species have maintained some of the best timber values. Trees that are straight and that branch high in their canopy represent the highest value within a given species. Trees with forks, several knots or visible wounds will have a lower timber value. The crowns of healthy trees will have large, vigorous leaves (not stunted, pale or wilted) and few dead branches. A tree with more than 15 percent dead branches in its crown indicates the tree is likely suffering from decline.

For a detailed explanation of related forestry practices, see “Internet Resources,” page 11.

## Shiitake Strain Selection

Shiitake strains have been bred and selected for many characteristics and purposes. For example, shiitake strains differ in the size, texture and ornamentation of mushroom caps. Strains differ in the length of their spawn-run period (see “Spawn Run,” page 5), in their response to cold-water forcing (see “Fruiting the Crop,” page 6) and in their tendency to fruit at different temperatures. Certain strains are preferred for indoor vs. outdoor cultivation. One may grow several strains to extend the fruiting season or to cover the range of growing season temperatures.

Strain integrity is maintained by storing mycelium in an inactive state at ultra-low temperatures to prevent genetic change. Samples of mycelium are brought out of frozen storage to produce vegetative spawn in pure culture as needed. High-quality spawn of known strains is well worth the price.

Ask your reputable spawn provider (consider *Field and Forest Products, Inc.*; see “Internet Resources,” page 11) for guidance in selecting strains appropriate to your climate and production needs. University of Missouri Center for Agroforestry (UMCA) research has shown WR46 (a wide-temperature strain) produces best under Missouri conditions. Night Velvet (a warm-weather strain) produces especially beautiful mushrooms.

Spawn is sold in plastic bags that contain 5 to 10 pounds of colonized amended sawdust. Bags have a breathing patch of mesh fabric that permits gas exchange and prevents fungus suffocation without permitting contamination. Each block of spawn consists of brownish sawdust bound together by white mycelium, all covered with a white mycelial felt with brown patches. Mushrooms may even form inside the bag and should be discarded or eaten. Spawn should be ordered several months in advance of need, to allow for production time. The supplier should try to ship the spawn to arrive just prior to planned inoculation.



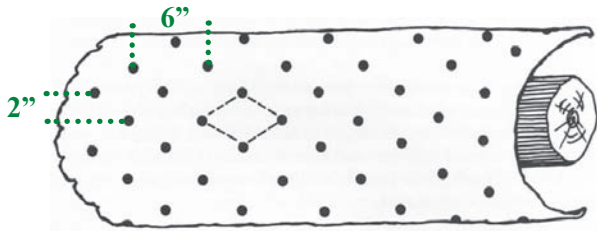
Holes are drilled in cut logs using an extremely high-speed drill.

## The Inoculation Process

Logs cut from healthy trees are inoculated with shiitake spawn inserted into holes made in the substrate logs using an extremely high-speed drill. Holes should be approximately 1" deep, separated by 6" along rows 2" apart and staggered to produce a diamond pattern (see *diagram page 5*). The inoculation process should be conducted in the shade to conserve moisture.

Spawn can be purchased in several forms: “traditional” loose sawdust spawn; styrofoam-capped “thimble” spawn; or wooden dowel spawn. Wooden dowel spawn has been recommended for late autumn

## Inoculating and Sealing



Drill holes 1" deep in a diamond pattern, separated by 6" along rows 2" apart. If inoculation holes are spaced too far apart, spawn run will be incomplete and contaminating fungi will gain a foothold. (Image courtesy Mary Ellen Kozak and Joe Krawczyk, "Growing Shiitake Mushrooms in a Continental Climate.")



Spawn should be injected immediately into pre-drilled holes in the log using a spring-loaded thumb injector. Any delay between drilling and inoculation will promote desiccation and contamination of the logs. These supplies are available from commercial mushroom suppliers, such as Field and Forest Products, Inc. (see page 11).



Hot cheese wax is applied immediately to seal inoculum into the log to prevent spawn desiccation. Note the sizzling of the wax when applied to the inoculum.

inoculation because it may be less likely to frost heave from the log during cold winter weather. Research has shown at HARC that logs inoculated with loose sawdust spawn produce best regardless of season of inoculation. Although thimble spawn produces quite well, it more expensive and is

produced in non-recyclable plastic sheets. The dimensions of dowel, loose sawdust and thimble spawn differ slightly, so attention must be paid to the depth and diameter of holes drilled. Screw-tipped auger bits with adjustable collar stops work best.

Holes should be filled with spawn immediately after drilling to prevent desiccation and contamination. Dowel spawn is inserted with a hammer; loose sawdust spawn is inserted with a spring-loaded thumb pressure spawn-plunging tool; and thimble spawn is inserted with thumb pressure. When using dowel or loose sawdust spawn, be careful not to leave the dowel protruding or overfill the holes.

Dowel and loose sawdust spawn need to be covered immediately with sizzling-hot wax (cheese wax is generally preferred), using a simple daubing device. The hotter the wax, the better the seal. If the dowel is left protruding or the sawdust spawn is mounded, the wax seal will be vulnerable to damage. The styrofoam cap on the thimble spawn provides sufficient protection from desiccation and contamination.

## Spawn Run

A thread-like network of mycelium grows from the spawn into the inoculated log. The period of time during which the mycelium initially colonizes the log (the "spawn run") requires about a year.

Logs should be stacked loosely after inoculation for the spawn run (pre-production) period to allow for initial log colonization. Appropriate log orientation depends on your ability to protect the logs from wind and sun. If your region has high humidity or you are able to sprinkle your logs with water during dry weather, you can stand the logs up or crib stack them loosely. Otherwise, logs can be lain horizontal on rails elevated 4" to 6" off of the ground. Logs should never be in contact with soil, to avoid contamination.

Optimal log moisture content for shiitake spawn run is 35 to 45 percent. Moisture conservation is best achieved by protecting logs from wind and sun while maintaining enough ventilation to allow bark to dry after periodic sprinkling to simulate a soaking rain. Constantly moist bark can foster the development of molds and other competing decay fungi, resulting in premature bark loss.

Although logs inoculated between December and May will produce a few mushrooms by the following

autumn, they should not be “forced” to fruit (see “Fruiting the Crop, next section) until the following

spring to assure good spawn run. Energy devoted to fruiting slows the spawn run process and can give competing fungi an advantage.

### Fruiting the Crop

The timing of mushroom production in nature depends on both temperature and the timing of precipitation. Once a log has “flushed” (produced a crop of mushrooms), it should be allowed to “rest” for 10 to 12 weeks to provide the mycelium time to replenish the energy required for fruiting. Thus, forcing 8 to 10 percent of one’s logs to fruit every week permits constant fresh production to meet market demand. When logs are forced to fruit too frequently, fewer and smaller mushrooms are produced.

Forced fruiting involves submersion of logs in cool water for approximately 20 hours. UMCA research has demonstrated that use of 52-degree F water stimulates more fruiting than warmer water.

This practice will also result in earliest recovery of log value by stimulating both wood decay and fruiting. As a result, logs will return their optimum value more quickly than with only natural rainfall.

Wide temperature range and warm weather strains of shiitake spawn respond well to this method of forcing. Cool weather strains respond to air



*Inoculated oak logs have been carefully cut to size for proper stacking in a simulated forest shade environment at the Ozark Forest Mushrooms commercial shiitake operation. Selected saw-timber trees grown on the premises are cut and sold to sawmills; residual branch-wood is the main source for shiitake logs. Spent logs should be removed from the production area to avoid contamination by competing molds and decay fungi, and can be burned for heat in a year-round greenhouse. Top image: Crib stacks for holding logs during “spawn run.” Logs should be well-spaced in crib stacks to prevent mold development. These logs will be relocated under a forest canopy to begin “fruiting” (inset). Then, during fruiting, these logs will be placed upright on end for more efficient mushroom picking.*

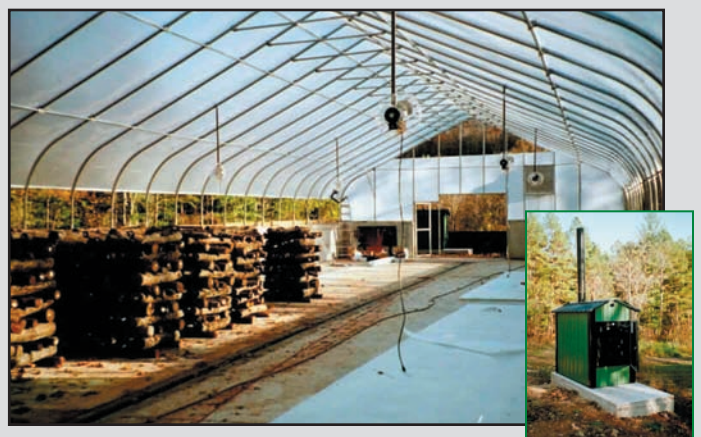
### Winter Production: Creative Recycling of Spent Logs

*In the right setting, shiitake can be produced indoors during the winter. Shade and light levels, ventilation and temperature must be controlled to recreate the outdoor fruiting season environment. In the late autumn, logs that have just completed their first fruiting season (logs in prime condition) are moved into the greenhouse for this purpose.*

*Dan Hellmuth and Nicola McPherson, proprietors of Ozark Forest Mushrooms, have built a greenhouse with a radiant heated concrete floor and are using spent shiitake logs to provide much of the fuel for heating this indoor winter cultivation facility.*

*“We’re not actually depleting our forest resources over time,” Hellmuth said. “Basically we’re turning waste wood into high-value mushrooms and then using the spent logs for fuel to heat our greenhouse to continue production throughout the winter.”*

*(At right: Ozark Forest Mushrooms’ greenhouse facility. Inset: The wood-burning boiler provides hot water for the radiant slab greenhouse floor.)*





Top: Shiitake logs soak overnight in a stock-watering tank equipped with a drain. Inset: At this point, developing mushrooms may be protected from both desiccation and heavy rain by covering logs during fruiting with horticultural fabric (see below).

temperature fluctuations in spring and autumn, but are unresponsive to soaking. For this reason, growers often prefer to inoculate their largest logs with cool weather strains because they do not need to be moved to a tank for soaking and can be left to fruit naturally in response to changing temperature.

When logs inoculated with wide-range or warm temperature strains begin to fruit spontaneously in the early spring, it is time to initiate a forcing routine.

Logs should begin to “pin” (initiate mushrooms), often at inoculation sites, within a few days after soaking. Once the bark surface dries after removal from soaking, the logs may be covered with a horticultural fabric to prevent both desiccation during dry weather and watersoaking during heavy rains. However, if the fabric blocks too much light, the mushrooms will develop longer stems and smaller caps. Fruiting should be complete in approximately one week.

Water is also needed for occasional thorough sprinkling during summer droughts. Logs should not be continuously watered, and the bark surface should dry out between waterings to minimize development of destructive surface molds and competing decay fungi. Log ends should be kept off the ground (or on weed barrier fabric) to prevent colonization by soil-borne decay fungi, such as *Armillaria* (the honey mushroom).

Indoor commercial shiitake production presents its own special challenges, requiring environments

similar to outdoor conditions, with variable temperature, lighting, humidity and ventilation. Indoor production facilities are vulnerable to build-up of pests and mold populations if the environment is not properly maintained.

## Harvesting

Mushrooms develop over a several day period, depending on temperature and moisture. Mushrooms should be harvested when their caps are 70 to 90 percent open (expanded), while the cap margin is still slightly inrolled. Agricultural shade fabric can be used during fruiting to both minimize mushroom desiccation and to protect mushrooms from absorbing too much water during rainfall. Mushroom development is much faster during warm weather than cool weather. As a result, nearly mature mushroom caps can expand beyond prime marketable condition overnight during very warm weather.

Harvest mushrooms by twisting and pulling the stem off of the log. Cutting the mushroom stem will shorten the shelf-life by causing the mushroom to dry out through the cut stem. Leaving the mushroom stem in the woods can increase insect pest problems.



Harvested mushrooms should be taken to market as quickly as possible following harvest. While shiitake have a good shelf life compared to other mushrooms, their quality begins to deteriorate slowly after harvest. Clearly, a better price will be obtained for the freshest mushrooms. The best price is obtained through retail sales to restaurants or at farmers’ markets. Fresh mushrooms should be stored in well-ventilated, humid containers like paper bags or cardboard cartons.

## Pest Management

Properly inoculated, shiitake are relatively pest resistant. The main considerations in pest management are to maintain proper inoculation density, prevent log desiccation and avoid log contact with the soil. Proper spacing of inoculation points, and prompt filling and sealing is essential for efficient spawn run. If inoculation sites are spaced too far apart, or if inoculation is delayed, other decay fungi will become established in the log and reduce shiitake production accordingly.

Correspondingly, as shiitake mushroom production begins to decline after several years, logs become a liability due to the build-up of contaminating fungi. Smaller logs are generally consumed more rapidly than larger. Logs that produce abundant fruiting bodies of competing fungi should be removed from the commercial production area, because fruit bodies of contaminant fungi are producing spores that increase their presence in the production area.



Above: *Stereum* (a contaminating wood decay fungus) fruiting on log end between rows of inoculation sites. Inset: Snail feeding on shiitake cap.



People aren't the only animals that enjoy shiitake. The key to minimizing stress in this regard is to grow enough shiitake to supply the neighborhood! Mice will leave occasional incisor marks on mushrooms they have tested for quality, but they cause little damage. Mushrooms forming close to the ground may harbor irritating numbers of fungus gnats between the gills, and slugs and snails can damage shiitake caps during prolonged humid weather. Finally, shiitake cultivation involves substantial activity in the production area, which can result in disturbance and compaction of the forest floor. Unmanaged, this disturbance can stress the trees producing the shade required for mushroom

production. Thus, it is very important to establish a "traffic pattern" in the production area that minimizes compaction.

## Shiitake: An Emerging Market

Markets for shiitake and other specialty gourmet mushrooms continue to show promising profit potential for Missouri forest land owners. Interest in fresh locally grown shiitake mushrooms is increasing with gourmet chefs, farmers' markets and household consumers, as information spreads about their nutritional benefits and rich, versatile taste.



Fresh shiitake mushrooms harvested from Ozark Forest Mushrooms are packed in cardboard containers for delivery to chefs and restaurants, left inset. Top and right inset: Value-added dried mushroom mixes are paired with locally grown rice for an attractive and consumer-friendly retail product.

## Ozark Forest Mushrooms carves market niche

One of the Midwest's most significant demonstrations of a successful forest farming practice is Ozark Forest Mushrooms near Eminence, Mo. Dan Hellmuth and Nicola McPherson established the mushroom operation in 1990 in the midst of what was then a timber operation. Together with a small staff, they coordinate every step of the value-added process, from procuring the logs to packaging consumer-friendly, locally produced mushroom products.

A key to their success is developing an agroforestry practice compatible with their land base. Under the guidelines of the Stewardship Incentive Program, administered by the Missouri Department of Conservation, Dan and Nicola recover a renewable supply of mushroom logs from the tops of harvested saw-timber trees, while simultaneously maintaining a healthy forest. Consequently, what began 18 years ago with only 100 oak logs in production

has grown to 16,000. Only five acres of the couple's 2,500 forested acres are used for actual mushroom production. Their outdoor production site is situated under a short-leaf pine canopy, which provides year-round shade.

Ozark Forest Mushrooms gives particular emphasis to targeted marketing of their value-added boxed mixes and products. "The biggest marketing challenge for a rural area is that most of the mushrooms are a fairly high-value specialty food, and the largest market is in some of the state's bigger cities," said Hellmuth. "We are marketing products in St. Louis and need to deliver them to the city on a weekly basis."

### *Prices and marketing strategies*

Many landowners fail at non-timber forest production by overlooking the importance of marketing research. Prior to beginning a specialty mushroom operation, investigate the possible markets in your area and know the price range you may encounter. Does the retail price compensate for the materials that will be needed? You should take the time to learn who your potential buyers are and what prices they are willing to pay. It is also helpful to learn how your local grocers place and price specialty mushrooms in the store, interview other growers and observe consumers purchasing mushrooms. Visit farmers' markets to see if they are being sold there, to whom and at what price. Contact restaurants to determine if they are interested in offering dishes prepared with fresh mushrooms. Don't forget about the market opportunities for mail order or Internet sales. Value-added products, like boxed mixes, sauces and dried mushrooms are another option.

In all markets, the relationship you establish with your buyer is critical. Be certain you have the production capacity before arranging an order. Remain in close contact with the buyer to ensure they have received the quality they were seeking.

Consumer education is also critical. Prepare a pamphlet for your buyer, telling them about the careful steps you take in production and ways to keep the mushrooms fresh in storage. McPherson gives customers a flyer telling the story of their operation, their local employees and the growing process. In an effort to reinforce the connection between customers and locally-grown foods, Ozark Forest Mushrooms has become part of a chef's

collaborative to promote local farms and foods to area restaurants.

"Cross-marketing with other locally grown foods helps build name recognition and an attractive connection to the local community," McPherson said. Keep in mind that the better the quality of mushroom you produce, the higher the price you can achieve. The best prices are obtained through restaurateurs. It is not uncommon to achieve a price of \$10 to \$15 per pound for fresh, high-quality shiitake sold to a restaurant. The lower prices you observe at supermarkets reflect the lower-quality mushrooms that growers are unable to sell to restaurants or at farmers' markets.

Additional markets include catering companies and organic food stores. Ozark Forest Mushrooms refrigerates its mushrooms within one hour of picking to retain optimum freshness and quality, and then ships directly or delivers to customers.

"As you try to manage your market, you should work toward producing a steady supply of mushrooms. Your customers will expect that," McPherson said.

### **Why Shiitake?**

The rich "umami" flavor and meaty texture of shiitake mushrooms is outstanding when sautéed, broiled, baked or grilled. A staple in the Asian diet for centuries, the shiitake mushroom has become the second-most consumed mushroom in the world. It is the third-most commonly consumed mushroom in the U.S., after white button and portobello mushrooms. In addition to great taste and versatility, shiitake are gaining worldwide recognition for health benefits.

Exotic mushrooms – including shiitake – have long been used for medicinal purposes in Asia. Lentinan, a natural complex carbohydrate found in shiitake, is used as a cancer treatment in Japan. In addition, the mineral selenium – shiitake are a good source – is being studied in the prevention and treatment of some types of cancer (selenium is a type of antioxidant), according to the National Cancer Institute's Web site, [www.cancer.gov](http://www.cancer.gov)

## Shiitake are nutritious

- Low in calories
- Low in glucose (beneficial for diabetics)
- Low sodium content
- High content of potassium and phosphorous
- High content of trace elements, including copper and zinc
- Good source of fiber and high-quality protein

**Umami** (oo-MA-mee): A meaty, savory, satisfying taste. Often described as the “fifth taste,” after sweet, salty, sour and bitter. Discovered in Japan in the early 20th century. Foods with the umami taste have high levels of glutamate, a building block of protein. MSG (monosodium glutamate) is a processed additive that can add umami taste to food. Umami is found in wine, parmesan cheese, anchovies and soy sauce, for example, in addition to shiitake.

## Recipes

### **Crisp Cucumber Shiitake Salad** *David Owens, modified by J. Mihail*

- 1/2 lb. cucumbers (pref. seedless; peel only if waxed)
- 1/2 T. salt
- 1/2 large red onion
- 2 C. finely sliced shiitake
- 2 t. salad oil
- 1/4 C. rice wine vinegar
- 2 T. honey
- 2 t. sesame oil
- black pepper to taste

Wash cucumbers and slice thin. Toss with salt and allow to drain in colander for 2 hours. Slice onion as thin as possible and set aside in large mixing bowl. While cucumbers drain, heat salad oil in heavy skillet just until smoking. Brown mushrooms in hot oil, cooking just until tender and seared. Remove from pan to cool. Combine remaining ingredients with onion and mix thoroughly. Add salted cucumbers and shiitake, toss to coat with the dressing mixture. Serve (makes 4 portions). Recipe scales up well!

### **Shiitake Soup** *Mary Ellen Kozak’s Mom*

- 1/4 lb. mushrooms, coarsely chopped
- 2 C. water
- 3 T. butter
- 3 T. flour
- 2 C. skim milk w/ shredded lion’s mane mushroom
- 1/4 C. onion, chopped

Pour water over 2/3 of the mushrooms and simmer 20 minutes. Melt butter, and saute the remaining mushrooms and all the onion until lightly browned. Add flour to butter/mushroom/onion mixture, and cook 5 minutes. Add milk mixture and broth/mushroom mixture, and simmer 5 minutes. Season with salt and pepper and serve.

### **Mushroom, Barley and Parsley Chowder** *J. Mihail*

- 1 1/2 lb. mushrooms
- 1/4 C. olive oil
- 2 large onions, chopped (or 3 leeks)
- 1/4 C. sweet Hungarian (or regular) paprika
- 1 can (14.5 oz.) Roma tomatoes
- 2 qts. regular-strength chicken or beef broth
- 2 C. water
- 1 C. pearl barley, rinsed
- 2 T. red wine vinegar
- 1 C. minced parsley
- salt and pepper

Slice mushrooms thinly. In a 6- to 8-qt. pan over high heat, combine mushrooms and olive oil. Stir often for about 15 minutes, until mushroom juices evaporate. Add onion and stir often for about 10 minutes, until limp. Stir in paprika, tomatoes (and packing juice), broth, water, barley and red wine vinegar. Over high heat, bring mixture to boil. Reduce heat to simmer, cover and cook about 30 min., until barley is tender. Stir in 3/4 of parsley, ladle into bowls; sprinkle with remaining parsley just before serving. Salt and pepper to taste.

### **Suggestions for cooking with shiitake**

- Virtually any recipe, including those calling for button mushrooms, will be improved with shiitake (eg. soups, stews, egg dishes).
- Consider grilling or broiling large shiitake basted with a mixture of olive oil, crushed garlic and soy sauce.

### **Zucchini Cheese Mushroom Custard** *J. Mihail*

- 2 T. butter or margarine
- 4 eggs
- 8 oz. shredded Monterey jack cheese (or cream cheese)
- 4 oz. shredded cheddar cheese
- 1/2 cup seasoned dry bread crumbs
- 2 cloves garlic, pressed

- 2 T.     grated onion
- 4 C.     coarsely shredded zucchini
- 1 C.     grated Parmesan cheese
- 1         small can green chiles
- finely diced shiitake

Coat bottom and sides of a shallow 2.5-quart baking dish with the butter. Beat eggs in large mixing bowl. Stir in cheeses, bread crumbs, garlic, onion, chiles and mushrooms until well blended. Fold in the zucchini. Scoop the mixture into the buttered baking dish. Smooth the top and sprinkle with Parmesan cheese. Bake uncovered in a 350 degree oven until top is well browned and center is firm (about 45 minutes). Cool 10 minutes before serving. Makes 8 to 10 servings.



## Additional Resources for Shiitake Production

### Internet Resources: Supplies and Information

Field & Forest Products, Inc. Growers' information, starter kits, spawn, cultivation tools and related products. [www.fieldforest.net/](http://www.fieldforest.net/) (800) 792-6220.

Ozark Forest Mushrooms. Commercial production of shiitake and other gourmet mushrooms. Growing process information and examples of value-added products. [www.ozarkforest.com](http://www.ozarkforest.com) (314) 531-9935.

Royse, D.J. Cultivation of Shiitake on Natural and Synthetic Logs. Penn State University. <http://pubs.cas.psu.edu/FreePubs/pdfs/ul203.pdf>

The Shiitake Mushroom Center. <http://www.shiitakecenter.com/index.html>

"The Mushroom Growers' Newsletter" is available at [www.mushroomcompany.com](http://www.mushroomcompany.com)

### Internet Resources: Forest Management

University of Missouri Forestry Extension: <http://extension.missouri.edu/explore/agguides/forestry>

Forest Management for Landowners, Missouri Department of Conservation: [www.mdc.mo.gov/forest/library/](http://www.mdc.mo.gov/forest/library/)

Optimum site conditions for North American tree species, United States Forest Service: [www.na.fs.fed.us/spfo/pubs/silvics\\_manual/table\\_of\\_contents.htm](http://www.na.fs.fed.us/spfo/pubs/silvics_manual/table_of_contents.htm)

### Books: Cultivation

Kozak, M.E., and J. Krawczyk. 1993. Growing Shiitake Mushrooms in a Continental Climate. 2nd Edition. ABC Printers, 3210 Hall Ave., Marinette, WI 54143.

Przybylowicz, P., and J. Donoghue. 1990. Shiitake Growers Handbook. Kendall/Hunt Publishing Co., Dubuque.

### Articles: Health Aspects

Mattila, P., K. Suonpaa, and V. Piironen. "Functional properties of edible mushrooms." *Nutrition* 2000; 16(7-8): 694-696.

Suzuki, S., and S. Oshima. "Influence of shiitake (*Lentinus edodes*) on human serum cholesterol." *Mushroom Science* 1976; 9: 463.

### Cookbooks

Anonymous. 1982. Wild mushroom recipes by the Puget Sound Mycological Society. Pacific Search Press.

Anonymous. 1988. Wild mushroom cookery from the Oregon Mycological Society. Oregon Mycological Society.

Czarnecki, J. 1995. A Cook's Book of Mushrooms. Artisan. New York.

Czarnecki, J. 1988. Joe's Book of Mushroom Cookery. Atheneum Publishers, New York.

Fischer, D., and A. Bessette. 1992. Edible Wild Mushrooms of North America – A Field-to-Kitchen Guide. University of Texas Press, Austin.

Freedman, L. 1987. Wild About Mushrooms – A Cookbook for Feasters and Foragers. Addison-Wesley Publishing Co., Inc., New York.

Hurst, J., and L. Rutherford. 1991. A Gourmets Guide to Mushrooms and Truffles. HP Books, Los Angeles.

Miller, H. 1993. Hope's Mushroom Cookbook. Mad River Press, Inc., Eureka, CA.

Snyder, J. 1994. The Shiitake Way. The Book Publishing Co., P.O. Box 99, Summertown, TN.

Wheeler, S. 1999. The Complete Mushroom Cookbook. Anness Pub. Ltd, London.

### Articles

Bruhn, J.N., M.E. Kozak, and J. Krawczyk. 2000. Woodland specialty mushrooms: Who grows them and what are the problems? In: L. Van Griensven (ed.), Science and cultivation of edible fungi: 535-542. Rotterdam: Balkema.

Gold, M.A., M.M. Cernusca, and L.D. Godsey. 2008. A Competitive Market Analysis of the U.S. Shiitake Mushroom Marketplace. HortTechnology 18(3): 489-499.

Kimmons, T.E., M. Phillips, and D. Brauer. 2003. Small farm scale production of aerobic compost from hardwoods predigested by *Lentinula edodes*. Journal of Sustainable Agriculture 23: 109-123.

### DVD

Agroforestry Five-Practices DVD (Forest Farming section). University of Missouri Center for Agroforestry. Available for purchase online at <http://www.centerforagroforestry.org/pubs/index.asp#dvd>

### Associations

The North American Mycological Association: Includes an annual directory and bimonthly newsletter. [www.namycology.org](http://www.namycology.org)

The Mushroom Council: Marketing and consumer trend information. [www.mushroomcouncil.org](http://www.mushroomcouncil.org)



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2nd edition; updated 2008



# MUSHROOM CULTIVATION AND MARKETING

HORTICULTURE PRODUCTION GUIDE

**Abstract:** The market for mushrooms continues to grow due to interest in their culinary, nutritional, and health benefits. They also show potential for use in waste management. However, as fungi, mushrooms have life cycles very different from those of green plants. The choice of species to raise depends both on the growth media available and on market considerations. Oyster mushrooms, which grow on many substrates, are easiest for a beginner. Shiitake mushrooms already have earned considerable consumer demand. Only two mycorrhizal mushrooms, morels and truffles, have been commercially cultivated. Mushroom cultivation offers benefits to market gardens when it is integrated into the existing production system. A careful analysis of potential markets must be the first step in deciding whether to raise mushrooms to sell. Many information resources are available for further research.

By **Alice Beetz** and **Michael Kustudia**  
 NCAT Program Specialists  
 July 2004  
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## Introduction

Small-scale mushroom production represents an opportunity for farmers interested in an additional enterprise and is a specialty option for farmers without much land. This publication is designed for market gardeners who want to incorporate mushrooms into their systems and for those farmers who want to use mushroom cultivation as a way to extract value from woodlot thinnings and other “waste” materials. Mushroom production can play an important role in managing farm organic wastes when agricultural and food processing by-products



Gray Oyster Mushrooms • Glen Babcock – Garden City Fungi

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are used as growing media for edible fungi. The spent substrate can then be composted and applied directly back to the soil. This publication includes resources for entrepreneurs who wish to do further research.

Many people are intrigued by mushrooms' nutritional and medicinal properties, in addition to their culinary appeal. Mushrooms contain many essential amino acids; white button mushrooms, for example, contain more protein than kidney beans. Shiitake mushrooms are less nutritious, but are still a good source of protein. (Royse and Schisler, 1980) As a group, mushrooms also contain some unsaturated fatty acids, provide several of the B vitamins, and vitamin D. Some even contain significant vitamin C, as well as the minerals potassium, phosphorus, calcium, and magnesium. (Park, 2001)

Asian traditions maintain that some specialty mushrooms provide health benefits. Chinese doctors use at least 50 species. Two recent books, *Medicinal Mushrooms: An Exploration of Tradition, Healing and Culture* and *Medicinal Mushrooms You Can Grow*, detail existing research on the health benefits of mushrooms. See the **Resources** section at the end of this guide for specifics on these books and other sources of information.

Mushroom production is labor- and management-intensive. Specialty mushrooms are not a "get rich quick" enterprise. On the contrary, it takes a considerable amount of knowledge, research, planning, and capital investment to set up a production system. You must also be

Producing nutritious food at a profit, while using materials that would otherwise be considered "waste," constitutes a valuable service in the self-sustaining community we might envision for the future.



prepared to face sporadic fruiting, invasions of "weed" fungi, insect pests, and unreliable market prices.

## Growing Mushrooms

Mushroom production is completely different from growing green plants. Mushrooms do not contain chlorophyll and therefore depend on other plant material (the "substrate") for their food. The part of the organism that we see and call a mushroom is really just the fruiting body. Unseen is the mycelium – tiny threads that grow throughout the substrate and collect nutrients by breaking down the organic material. This is the main body of the mushroom. Generally, each mushroom species prefers a particular growing medium, although some species can grow on a wide range of materials.

If you are considering mushroom production, become thoroughly familiar with the life cycles of fungi. A very general description is included below. A plant pathology textbook is a good resource for learning more about these complex life cycles.

Once you are familiar with the various fungi life cycles, learn the growth requirements of each of the species you are considering. Two basic references are *The Mushroom Cultivator*, by Stamets and Chilton, and the aforementioned *Growing Gourmet and Medicinal Mushrooms*, by Stamets (see **Resources**).

Growing mushrooms outdoors as a part of a market garden involves little effort after you have inoculated the logs or other substrate with the mushroom spawn. Your duties are mainly to maintain humidity and monitor for fruiting. When mushrooms appear, you add them to your other garden products and sell them. (See *Mushrooms on the Farm and in the Garden*, below.)

Most available markets, however, require more mushrooms than occasional fruiting provides. Indoor production can fill the gaps when outside fruiting lags. The entire operation can also be conducted inside. However, indoor mushroom production demands a much higher level of knowledge, continuous monitoring, and timely manipulation of environmental conditions.

These are the steps in mushroom production— a cycle that takes about 15 weeks (time varies by species) from start to finish.

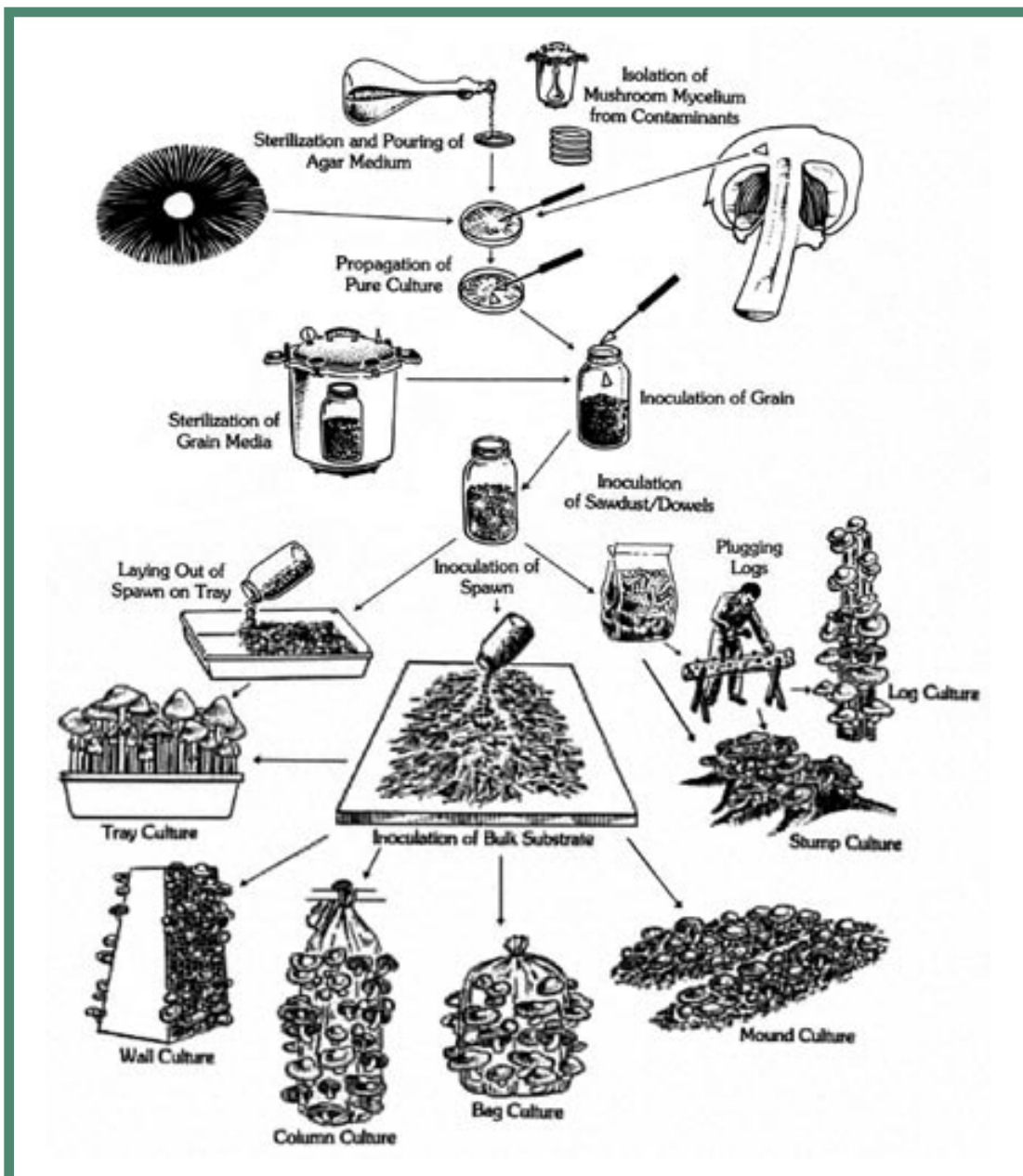
- Choosing a growing medium
- Pasteurizing or sterilizing the medium
- Seeding the beds with spawn (material from mature mushrooms grown on sterile media)
- Maintaining optimal temperature, moisture, and other conditions for mycelium growth and the conditions that favor fruiting (This is the most challenging step.)
- Harvesting, packaging, and selling the mushrooms

- Cleaning the facility and beginning again (Cooner, 2001)

The substrate on which the mushrooms will fruit must be sterilized or pasteurized in order to destroy any fungal and/or bacterial competitors. Low-tech substrate preparation methods are described in the books by Paul Stamets and by Peter Oei (see **Resources**).

To produce spawn, you inoculate a pasteurized medium, usually grain, with the sterile culture of a particular mushroom species. After the culture has grown throughout the medium, it is called spawn. Producing spawn requires exacting laboratory procedures. Terri Marie Beauséjour,

Figure 1



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cultivation chair for the Mycological Society of San Francisco, has written an excellent article that can help the beginner who is put off by the technical aspects of mushroom cultivation. Titled "Getting Started with Mushroom Cultivation: The Wisdom of Simplicity," it is available on the Web at <[www.mykoweb.com/articles/cultivation.html](http://www.mykoweb.com/articles/cultivation.html)>.

Many mushroom suppliers sell several kinds of spawn, and the beginning mushroom farmer should take advantage of this selection in early trials to determine which species grow best on available materials. Eventually, learning to produce spawn might reduce your cost of produc-

tion. Evaluate this possibility only after you have mastered the later stages of cultivation.

While the mycelium is growing—and until it fully occupies the substrate—the mushroom farmer typically manipulates the growing environment to favor mycelial growth. The atmospheric conditions are then changed to initiate "pinheads," and then to complete fruiting. For example, in oyster mushroom production under closely controlled conditions, the grower lowers the temperature and the CO<sub>2</sub> in the grow room to initiate fruiting. Each species has specific requirements for its stages of development. *The Mushroom Cultivator* provides detailed

## Mushrooms in Permaculture\* Design

*\*Permaculture is a system of combining perennials, trees, shrubs, and vines to create a "permanent agriculture." Using an intensive design process, the natural elements of an ecosystem are replaced by food-producing relatives, creating an edible landscape.*

Paul Stamets was an early advocate of integrating a variety of mushrooms into a permaculture system. (Stamets, 1994) In his design, agricultural wastes like cornstalks, wheat straw, or rice straw can be used as growing media for oyster mushrooms. After harvest, the spent substrate can be recycled as fodder or mulch for garden soils.

Shaggy manes (*Coprinus comatus*), Stamets notes, do well on manured soils and near compost piles. The King stropharia or wine cap mushroom (*Stropharia rugoso-annulata*) grows best outdoors and plays a key role as a recycler of woody debris. Bees, attracted to the sweet mycelium, help pollinate the green garden plants. The mushrooms are good to eat when small. Large, mature mushrooms attract fly larvae that make excellent fish or poultry food. These can supplement feed for other on-farm enterprises or be sold to pet stores.

Stamets also uses King stropharia mushrooms for their ecological benefits. He found that, when established along

waterways, they acted as microfilters of fecal coliform bacteria generated by his small herd of cattle. He also planted them along greywater runoff areas. Stamets believes mushrooms can play a large role in mycofiltration. (Stamets, 2000-2001)

Stamets grows shiitakes, namekos (*Pholiota nameko*), and Lion's mane (*Hericium erinaceus*) mushrooms on inoculated logs set in a fence row, while other species like maitake (*Grifola frondosa*), reishi (*Ganoderma lucidum*), and clustered wood-lovers are cultivated on stumps as part of a hardwood forest management system. He introduces mycorrhizal species such as chanterelles, King boletes, and others to new areas by "satellite planting," in which seedlings are planted near trees that have a desired mushroom species growing around them. After several years, the seedlings and their mycorrhizal associates are transplanted, creating new patches of mushrooms. Morels are more difficult to propagate, but some types can be encouraged through the use of small burns.

information on the requirements for 16 species.(Stamets & Chilton, 1983)

When you can cut the time between harvests, annual production increases. Short cycles are what large-scale commercial producers aim for, constantly looking for ways to increase efficiency. This is the competition you face if you plan to sell your product on the wholesale market.

Paul Stamets of Fungi Perfecti, an educational and mushroom supply company (See **Resources**), has spent most of his life studying the growth and cultivation of fungi. His book *Growing Gourmet & Medicinal Mushrooms* (see **Resources**) is an invaluable resource for anyone considering the cultivation of any mushroom species. He describes several alternative methods of producing mushrooms, including growing them outdoors on logs, on stumps, and in the garden, as well as indoors in bags or on columns.

Peter Oei, in his *Manual on Mushroom Cultivation* (see **Resources**), describes in some detail how alternative mushroom production systems have been used successfully in developing countries. Many ideas for low-input systems are included. In practice, it is unlikely that the beginner can successfully compete in the wholesale market against highly capitalized and efficient mushroom companies. A better choice for the beginner is to develop a niche market for high-quality fresh mushrooms, then sell them at retail, or to produce a value-added mushroom product, such as a soup mix or sauce.

## Mushrooms on the Farm and in the Garden

Fungi cycle nutrients that nourish new life in the soil. Recognizing this essential function, inventive gardeners integrate mushrooms into farm, garden, and permaculture systems. Mushrooms can also be grown in lawns, polytunnels, vegetable gardens, and woodlands.(Edwards, 2000)

Terri Marie Beauséjour, a writer for *Mushroom the Journal*, encourages creativity and imagination when planting mushrooms in a garden. Look at the “fungamentals,” she writes, the necessities such as available substrates, microhabitats, sun,

shade, wind, and humidity conditions. Gardens offer ample substrates—organic waste materials—while plants provide shade and humidity. Plug-inoculated blocks buried among plantings work well for oyster and *Stropharia rugoso-anulata* mushrooms. Beauséjour suggests using a misting sprinkler for mushrooms in gardens. (Beauséjour, 1999)

Grower and author Ken Litchfield notes that mulching, a standard gardening practice, not only regulates soil temperature and humidity but also nourishes fungi. He also suggests surrounding raised beds with partially buried logs to create mushroom habitats. Inside the beds, vegetables, flowers, and shrubs offer the requisite shade and humidity for mushroom cultivation. In weedy areas, Litchfield suggests putting down organic material and covering it with wet cardboard and wood chips, an ideal substrate for fungi.(Litchfield, 2002)

These methods of production are not likely to yield huge numbers of mushrooms. However, they can provide an attractive addition to directly marketed produce.

## Choosing a Mushroom Species

A mushroom cultivation kit (check with suppliers listed below) is a handy way to begin to understand the fungal life cycle. Once you successfully use the kit, you can begin to learn the steps that precede that final fruiting stage of the mushroom life cycle. Purchase spawn that will grow on materials you have available. Then design and test a system that duplicates the conditions favorable to all stages of growth. You can use this experience to learn how to create sterile cultures and spawn for the species you are growing.

Choose the species to grow by thinking about:

- What waste materials are readily available to use as a growth medium?
- What kind of facility or environment is available?

- How much will the necessary equipment cost?
- What level of skill is required to manage the life cycle of the fungus?
- What is market demand for this species?

According to these criteria, oyster (*Pleurotus species*) and shiitake (*Lentinus edodes*) mushrooms are probably best for most novices, although the maitake (*Grifola frondosa*) is also a possibility. The former two are relatively easy to grow, and there is already a market for them, largely because commercial producers of white button (*Agaricus bisporus*) mushrooms have been diversifying into specialty mushrooms. If you intend to grow mushrooms commercially, shiitake or oyster mushrooms are your best choices. These two species are more thoroughly covered in the following sections.

A chart in the **Appendix** lists other common species and the materials on which they can be cultivated. Test each species you are considering against each of the questions listed above.

## Species for Beginners

### Oyster mushrooms

Oyster mushrooms (*Pleurotus species*) are a good choice for beginning mushroom cultivators because they are easier to grow than many of the other species, and they can be grown on a small scale with a moderate initial investment. Although commonly grown on sterile straw from wheat or rice, they will also grow on a wide variety of high-cellulose waste materials. Some of these materials do not require sterilization, only pasteurization, which is less expensive. Another advantage of growing oyster mushrooms is that a high percentage of the substrate converts to fruiting bodies, increasing the potential profitability.



Flamingo Oyster Mushrooms • Glen Babcock – Garden City Fungi

Oyster mushrooms can become an integral part of a sustainable agriculture system. Many types of organic wastes from crop production or the food processing industry can be used to support oyster mushroom production.

Although there are no books devoted entirely to oyster mushroom production, Stamets' books provide basic information. Research on using various agricultural and forest wastes as substrates is reported in the recently published *Mushroom Biology and Mushroom Products*, edited by D.J. Royse. (Royse, 1996) Peter Oei (Oei, 1991) documents a number of commercial production systems for some strains grown in developing countries.

There is an increasing number of Web sites devoted to oyster mushroom production. Lawrence Weingarten describes his production process on his Web site, complete with photos at <[www.mycowest.org/cult/i-grow/i-grow-1.htm](http://www.mycowest.org/cult/i-grow/i-grow-1.htm)>.

Two Canadian Web sites also offer additional advice:

- Oyster Mushroom Cultivation  
[www.gov.ns.ca/nsaf/elibrary/archive/hort/vegetables/pihve94-03.htm](http://www.gov.ns.ca/nsaf/elibrary/archive/hort/vegetables/pihve94-03.htm)



Golden Oyster Mushrooms • Glen Babcock – Garden City Fungi

- Growing Shiitake & Oyster Mushrooms on Hardwood Logs  
[www.fallsbrookcentre.ca/webmain/programs/Forest/Pamphlet.htm](http://www.fallsbrookcentre.ca/webmain/programs/Forest/Pamphlet.htm)

The MushWorld Web site, <[www.mushworld.com/home](http://www.mushworld.com/home)>, contains excellent technical information about growing oyster mushrooms. The site requires registration, but it is free.

Oyster mushroom cultivation has one significant drawback: some people are allergic to the spores. In these cases, air-cleaning equipment or respirators are necessary in order to safely work in the production facility.

The consumer market for oyster mushrooms is being developed by the larger mushroom companies as they diversify their operations. However, because of the short shelf life of many oyster mushroom varieties, this species may offer a special advantage to the local grower who markets directly and can consistently deliver a fresh, high-quality product.

## Shiitake mushrooms

Shiitakes (*Lentinus edodes*) are well suited as a low-input alternative enterprise because they, like oyster mushrooms, can be grown on a small scale with a moderate initial investment. Shiitake cultivation has been thoroughly investigated, and a commercial market already exists in most areas of the United States. Shiitake mushrooms are

grown on logs, either inside or outside. Inside, they can also be grown on compressed sawdust logs or in bottles or bags. See the brief description of these production systems below. Several excellent books and Web sites are also listed below in **Resources (shiitake)**.

## Log Production

Hardwood logs approximately 4" to 6" in diameter and of an easily handled length (commonly four feet) are cut during a tree's dormant season. Oaks, sweetgum, cottonwood, beech, birch, willow, and other non-aromatic hardwoods are appropriate species. The denser woods produce for up to twice as long as the softer ones. Smaller diameter logs produce more quickly than larger ones, but for a shorter time.

Handle the logs carefully to avoid soil contact and damage to the bark. This will help prevent contamination by competing fungi. Inoculate the logs with spawn from a strain suitable to your production system. There is a wide variety of spawn from which to choose and several inoculation methods.

After inoculation, the spawn develops a thread-like network – the mycelium – growing throughout the log. During this time, you must protect the logs from dehydration by the sun and wind. Spray or mist the logs to maintain the humidity necessary to keep the mycelium alive and growing. When the mycelium has fully occupied the logs and the temperature and humidity are right for fruiting, the mycelium will initiate tiny "pinheads" at the surface of the log. The pinheads grow into mushrooms in the next couple of days.

To stimulate fruiting, some growers soak the logs in water tanks and/or "shock" them by physical impact or chilling. Others leave the logs in the growing environment and harvest when they naturally fruit.

Be alert for signs that fruiting is beginning. The best grades of shiitakes have caps that still have a slight curl at the edge. Harvest often if you want to earn the best price for your mushrooms. In addition, if you want to deliver a premium product, you must pay attention to post-harvest storage, packaging, and shipping.

Many shiitakes are raised organically. Although it is easier to produce shiitakes organically than some of the other mushrooms, “weed” fungi, as well as pests such as slugs and flies, can reduce fruiting and quality. The producer must monitor, quickly identify, and control these pests or lose some of the crop.

Federal law now controls the use of the word “organic” in marketing. In order to label a product organic, producers must be certified by an accredited third party and document their production and handling practices. For further information, call and request the ATTRA publication *Organic Farm Certification & the National Organic Program*, or see it at our Web site, <[www.attra.ncat.org](http://www.attra.ncat.org)>.

### Growing Shiitakes on Sawdust

Today, most shiitakes and many other mushroom species are raised on a sterilized sawdust substrate. Although this method allows a much faster fruiting cycle and a high level of return (110% or more of initial dry weight), it also demands a greater capital investment and more skillful management than log production. In order to achieve fruiting as quickly as possible, you need a building in which you can control the temperature and moisture. The building must be easy to keep clean, and sanitary procedures must be strictly followed to avoid contamination.

The chamber and the steam processor to pasteurize or sterilize the sawdust can represent a significant initial investment. For example, Crop King sells a small mushroom production system, including an inoculation table and bagging station, for about \$5,000. The company’s complete growing system—including equipment, structural components, and technical support—can come to more than \$41,000. Recovering these costs is a challenge for a beginner—especially at current mushroom prices.



Shiitake mushrooms fruiting on sawdust • Glen Babcock - Garden City Fungi

However, innovative producers have used concrete mixers to blend supplemental ingredients and made pasteurized substrate in barrels. Fungi Perfecti sells pressure sterilizers for \$200 to \$1,000, but warns that they are not designed for commercial production.

Using hydrogen peroxide instead of conventional pasteurization is a relatively recent innovation. A manual on this method and more information is available at <[www.mycomasters.com/](http://www.mycomasters.com/)>.

Growing mushrooms on sawdust requires attention to detail—especially careful monitoring and timely processing of the blocks, bottles, or bags. Several of the books listed below, including Stamets (1993) and Przybylowicz and Donoghue (1990), offer more details about this production method.

### Shiitake Prices

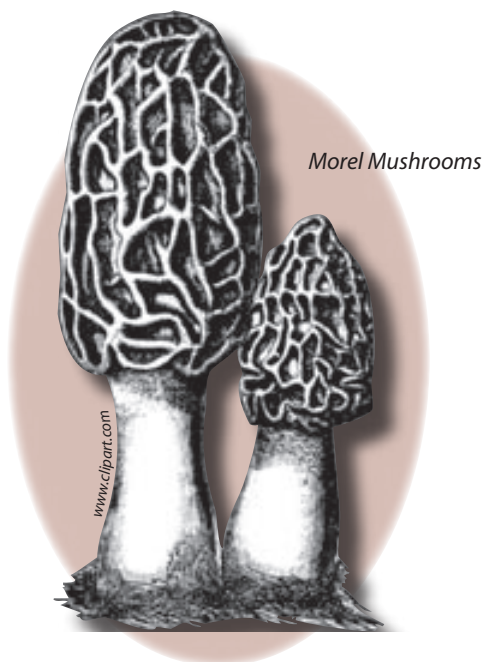
The price for shiitake mushrooms fluctuates throughout the season. Prices are highest in the winter when supply is low, and lowest in summer when production peaks. Except in very mild climates, the only logs that fruit in winter are those maintained indoors. Using strains selected to fruit at cooler temperatures can lengthen the

harvest season and allow producers to capture the higher prices. See the marketing section below for ways to counteract the natural price cycle.

### Sources of Further Information on Shiitakes

Several states, including Pennsylvania, California, and Oregon, support university research on shiitakes and may have Extension specialists who can provide information to growers in their states. Others have Extension publications with information specific to their areas. Some of these resources are available on-line at Web sites listed in the **Resources** section. An excellent example is the site maintained by the Ohio State University.

In states without this Extension support, one of the best ways to learn about production is to share information with other growers. There are several local grower organizations, many of which publish newsletters. Ask your state Extension horticultural specialist about local organizations, or you can contact the North American Mycological Association or the American Mushroom Institute (see **Resources**). There are also several books specifically about shiitake production. See **Resources (shiitake)** for more information.



## Other Mushroom Species

### Mushroom Species with Limited Commercial Production

Some species of mushrooms are not yet commercially cultivated. Many of these are mycorrhizal types; that is, they grow only in conjunction with the roots of a higher plant. Matsutakes and chanterelles are typical examples of such mushrooms.

Mycorrhizal mushrooms are the hardest to grow commercially, because the needs of both the fungus and the host plant must be met in order to produce a commercial crop. Also, the host plant typically must reach a certain physiological maturity before the fungus will fruit. When the host is a tree, this maturation may be measured in decades. Nevertheless, highly prized morels and truffles are mycorrhizal, and they are both now being grown commercially in the United States.

#### *Morels*

Commercial production of morels on anything but a small-scale, seasonal basis is currently not a practical option. Morels are being grown year-round, using a patented process, at only one production facility in North America (in Alabama). The patent and facility are owned by Terry Farms and represent the only successful commercial process for fruiting these highly valued mushrooms out of season.

It is, however, possible to establish a morel patch by using a morel starter kit. If you are successful, these mushrooms will fruit in the spring at the same time as wild morels. Morel prices are, understandably, at their lowest during this natural fruiting season. Adding them to a farmers' market stand would certainly attract more-loving customers. You can also dry the product for year-round sales if you can grow commercial quantities in your patch.

Tom Volk's Web site, <[http://botit.botany.wisc.edu/toms\\_fungi/morel.html](http://botit.botany.wisc.edu/toms_fungi/morel.html)>, has particularly good information about morel mushroom production.

#### *Truffles*

Growers generally begin truffle production by

dipping tree seedlings in a mycorrhizal slurry before planting. After several years, under favorable growing conditions for both the tree and the fungus, truffles form underground fruiting bodies that roughly resemble potatoes. These range from the size of a pea to that of a fist and give off a distinctive odor. Since these “mushrooms” don’t completely emerge from the ground, they have traditionally been sniffed out by pigs or trained dogs.

The requirements for growing the black Perigord truffle, *Tuber melanosporum* Vitt., include choosing an appropriate host plant (usually oak or hazelnut), inoculating its roots with the spawn, and planting it. Frank Garland planted his first inoculated trees in 1980 and harvested the first black truffles grown in the U.S. on October 23, 1993. He has written a production guide based on his experience. (Garland, 1996) Garland also has a consulting business and sells inoculated trees.

One Oregon tree farmer in prime white truffle country found a low-fuss method of cultivation. The white truffle, *Tuber gibbosum*, is a mycorrhizal species associated with Douglas fir and other conifers. This farmer uses a backpack sprayer to apply a slurry made of truffles and spores at the roots of conifers. The inoculated areas have produced between 300 to 1000 pounds per acre per year, significantly more than the unsprayed areas. (Arnold, 1996)

The truffle industry has developed rapidly in Australia and New Zealand. New Zealand’s efforts, as reported by Dr. Ian Hall, were begun in 1987, with harvest recorded on June 29, 1993, just months before Garland found his first truffles in North Carolina. (See <[www.fungifest.com/article1021.html](http://www.fungifest.com/article1021.html)>.) Australian researchers also report success in their cultivation efforts, summarized in several articles available on the Web. The articles are found by searching the following main pages for “truffle” or “*Tuber melanosporum*”:

- [www.crop.cri.nz](http://www.crop.cri.nz)
- [www.rirdc.gov.au/reports](http://www.rirdc.gov.au/reports)

*The Black Truffle* (Hall et al., 1994) is out of print, but it was converted to CD ROM format in 2001 and is available for NZ\$49.95 through the Internet at <[www.crop.cri.nz/psp/products/truffle.htm](http://www.crop.cri.nz/psp/products/truffle.htm)>. Chapters cover the symbiotic partnership between truffles and their host plants, his-

tory and folklore, cooking and recipes, how to establish and manage a plantation, climatic and soil requirements, and cultivation and harvesting.

Studies have revealed a lot about the conditions necessary to bring truffles to early fruiting and then to significant production levels. However, because of the crop’s extremely high value and because each success has required an investment of considerable time, it is understandable that some of this information is considered proprietary. Even when fruiting begins, growers themselves may not be able to accurately identify what contributed most to the truffles’ growth.

Each new truffle enterprise is an experiment based on what has already been reported. Check this Web site maintained by a group of scientists investigating truffle cultivation: <[www.truffle.org/tuber\\_directory/](http://www.truffle.org/tuber_directory/)>.

Consider combining the production of truffles with the sale of nuts from the host trees, growing annual or perennial crops between the trees, or grazing ruminants among them—sheep have been credited with increasing the French wild-harvested crop yield. (Ludmer-Gliebe, 1997) These or other agroforestry options could provide additional sources of income during early, non-fruiting years and in the seasons when truffles do not produce.

### Other Mycorrhizal Species

Mushroom researchers continue to investigate the cultivation of other species for the



commercial market. A loosely organized group of international scientists meets intermittently to share their research. The Web site maintained for this scientific endeavor is <[www.mykopat.slu.se/mycorrhiza/edible/home.phtml](http://www.mykopat.slu.se/mycorrhiza/edible/home.phtml)>.

Until commercial production systems are developed, mushrooms such as chanterelles and matsutake (pine) mushrooms will continue to be collected from the wild for sale to the specialty mushroom market. The harvest of wild mushrooms is strictly regulated in some states. Check with your state department of agriculture regarding laws that apply. You would be wise to carry liability insurance and to be absolutely certain of the identity of mushrooms you sell. Mistakes can be fatal to the consumer. Finally, the forest environment that supports the growth of wild mushrooms is a fragile one. Learn how to conduct your foraging business in a way that protects future harvests.

*Mushroom the Journal* (see **Resources**) provides excellent information on wild mushrooms. There are also many local mycological societies that schedule “forays” – trips to known mushroom habitats – where the inexperienced forager can learn about various species and how to identify them.

## Pest Management

Integrated pest management (IPM) is a least-toxic approach for managing any pest. IPM views pests as a natural part of the farm environment. The integrated management of a pest is accomplished by altering the environment to the disadvantage of that pest. In order to accomplish this, you have to be able to identify what pests are active, how many there are, and how many it takes to hurt your profits. If you know the life cycle of each problem organism, you can take measures to make it hard or impossible for it to complete its life cycle. You may be able to encourage natural enemies that will keep the population below the economically damaging threshold.

Here are some examples of non-chemical methods used to control typical pests in the production of white button mushrooms. Mushroom flies, a common pest among many cultivated mushrooms, are attracted to the smell of decaying vegetation such as mushroom substrates. Screen-

ing the mushroom house ventilation system will keep adult flies out. Double doors and positive atmospheric pressure within the structure also prevent flies from entering. Since adult fungus flies are drawn to standing pools of water on benches, walks, or floors, places where water can collect should be eliminated. Biocontrol is another option for several mushroom pests, the sciarid fly among them. A predatory nematode attacks this fly in its larval form. Therefore, this nematode can be added to the composting substrate to prevent infestation.

For a better understanding of IPM, see the ATTRA publication *Biointensive Integrated Pest Management*. It describes IPM methodology and provides extensive resources for further research.

Each mushroom species in a specific environment has a different pest complex. Because specialty mushroom production in this country is still very new, many pests have not received research attention. Most pests you are likely to encounter, however, have probably already been studied. In any case, you will probably have to design your own pest management system. Stay alert for any evidence of damage to the fruiting mushrooms and act quickly to identify its cause. Use whatever information you can find, along with your own creativity, to devise ways to protect your crop.

Use all the resources you can find – in libraries, at bookstores, or on the Web. Local Extension agents or state Extension specialists can help identify pests and, possibly, determine economic thresholds. They can also help you find biological controls, if cultural and mechanical methods fail.

## Marketing Mushrooms

Marketing is the most important consideration of all. If you can't sell your mushrooms at a price that ensures a reasonable profit margin, you don't want to invest in this enterprise. Spend some time – and even some money – educating yourself about marketing your potential product.

This section provides a broad overview of market trends, some ideas about how to research potential markets, references to useful resources,

suggestions about marketing channels, and advice on financial analysis.

Market research and evaluation is perhaps the most challenging part of developing a new enterprise. Luckily, there are many helpful sources. A good place to start is ATTRA's Marketing and Business series, particularly *Direct Marketing* and *Evaluating a Rural Enterprise*. These publications detail the market evaluation process and include extensive resource lists. Other relevant ATTRA publications cover market gardening, value-added products, and agri-tourism. You can find the marketing publications on the ATTRA Web site at <<http://attra.ncat.org/marketing.html>>, or call 800-346-9140 to have them sent to you.

The many Web sites listed in **Resources** (below) will help you find information to further your market research. Another resource, as you analyze the potential for a mushroom business, is your local Small Business Administration office. Not only do they have helpful publications, they also provide some one-on-one assistance.

## Market Demand

Some 260 U.S. growers produced more than 844 million pounds of mushrooms in 2002-03, with a farm gate value of \$889 million. (Certified organic mushrooms accounted for only 1 percent of all sales, although 12 percent of growers were certified organic.) The vast bulk of sales were of the *Agaricus* species, which includes white button mushrooms, portobellas, and criminis. The latter two are a brown strain of *Agaricus bisporus*, whose cultivation is managed for extra large (portobella) and very small (crimini) fruiting bodies. (Current statistics are found at <<http://usda.mannlib.cornell.edu/reports/nassr/other/zmu-bb/>>.)

Large, well-established companies produce virtually all *Agaricus* mushrooms; most are located in Pennsylvania and California. Their production houses are full of mushrooms in every stage of development. Mushrooms raised in these systems can be sold profitably on the wholesale market. It is very difficult for a beginning grower to compete with these companies at wholesale prices.

## The Mushroom Business

Stella K. Naegely writes in the *American Vegetable Grower* that the key to the mushroom business is to have established buyers and be capable of consistent production. New growers might encounter an uphill educational experience for two or three years. Launching a commercial mushroom operation can cost between \$50,000 and \$250,000, depending on whether a grower starts with an appropriate building. For that reason, it is prudent to start small. Naegely offered the following business tips for people contemplating commercial production. (Naegely, 2000)

- Make the market drive your production. Talk to potential buyers about volume and prices.
- Explore various marketing options: brokers, distributors, farmers' markets, restaurants, grocery stores, food service operations, and co-ops.
- Consider reselling other growers' mushrooms to offer more variety and larger volume.
- Talk to other producers and perhaps a consultant about production systems.
- Consider buying used equipment to reduce initial capital investment.
- Strike a balance between undercapitalizing and a heavy debt load.

## Market Research

The goals of market assessment are to project the sales volume and gross income of a new enterprise, to analyze its potential profitability and cash flow, and to gather information about potential buyers and competitors (to help develop a market strategy).

Many specialty mushrooms can be cultivated, but the market, though growing, is still limited. If you are thinking about starting a commercial mushroom enterprise, begin at the end: to whom will you sell them? You cannot make money in any business if you don't have buyers for your product. Learn who buys mushrooms, what

kinds they want, and where they shop. You must thoroughly investigate the demand for each mushroom species or product— as well as the available marketing outlets— before committing large amounts of capital to the enterprise.

Check the local situation on your own. Some common methods for conducting initial research include observation of buyers, surveys of stores, personal interviews with growers, and test marketing (once you have an experimental product). Another function of market research is to evaluate the competition. This will help you determine what market already exists and identify any niches you could fill. To find out more about your competitors, use their products. Talk to them. You may be surprised how much information they will share.

### Market Channels

Explore as many marketing strategies as appeal to you. Below are some possibilities.

- Market the fresh or dried product directly to your customers (at farmers’ markets, to gourmet chefs, over the Internet, through mail-order offerings)
- Add value to the mushroom by creating processed products (mushroom sauces, dried entrée mixes, teas, extracts)

Shiitake mushrooms harvested from sawdust  
Glen Babcock – Garden City Fungi



- Wholesale as fresh produce (on contract or by the batch)

### Direct marketing

If you can sell your mushrooms or mushroom products directly to an end user, you will naturally receive a better price than if you sell to a wholesaler. Direct marketing of mushrooms at local farmers’ markets, to restaurants, or in supermarkets is possible in many locations. When competing in local markets, excellent service, top quality, and consistent supply, rather than the lowest price, might win the sale, particularly with gourmet chefs. Some chefs specialize in locally grown foods and may be interested for that reason. Others are willing to pay for fresh, premium produce. In any case, establishing a relationship with the buyer and reliably delivering a quality product are essential for this type of marketing.

Local grocery stores are another potential buyer of fresh mushrooms. However, an Arkansas grower found that local grocery chains were interested in her shiitake mushrooms only if she could assure them of a year-round supply. She decided that she had to add indoor production in order to meet this requirement. Natural foods stores are a market that may be more tolerant of seasonal supply. Any chef or grocer will require assurances of both quality and regular supply before switching from established wholesale sources.

Although the wholesaler with an established account creates stiff competition, the small, efficient producer might still have an advantage in some niche markets. For instance, shiitakes grown on logs are generally of higher quality and have a longer shelf life than shiitakes grown on sawdust substrates (the most common mass-production method). Log-grown shiitakes earn prices from three to eight times higher than those grown on sawdust substrates. (Anon., 2003) Find the buyer to whom

quality matters, and you will have found a market for your product.

Locally-grown oyster mushrooms have an advantage because oysters have a very limited shelf life and are too fragile to ship easily. The grower with direct, local sales can supply a fresher product that arrives in better condition.

### Wholesale markets

Selling fresh mushrooms to a wholesaler will mean a lower price than if you market directly. However, for growers who choose not to involve themselves in direct sales, there are established wholesale markets for mushrooms. Wholesalers advertise in produce industry periodicals like *The Packer*. Your local librarian or an Internet search can help you locate other such magazines.

Mr. Paul Goland of Hardscrabble Enterprises maintains that there is a steady and growing market for quality dried shiitakes, even though the wholesale market has been depressed by Chinese imports. His buyers—natural foods stores and co-ops—do not buy the Chinese products. He buys several grades of dried shiitakes from growers who ship directly to West Virginia. Contact Paul Goland (see **References**) to learn whether he has a current demand for your product.

Small-scale commercial production of white button mushrooms and other *Agaricus* varieties such as portobellas and criminis is not recommended for the beginner, except on a small scale for direct marketing. A significant capital outlay and a high level of management skills are required to begin production, and at current prices, recovery of the initial investment might not be possible. The market is extremely competitive. More information about the button mushroom business is available from The American Mushroom Institute (see **Resources**).

### Adding Value to Fresh Mushrooms

Adding value to fresh mushrooms usually means either developing a processed product, such as a sauce, or drying surplus mushrooms for sale in the off-season, when prices are higher. A value-added product can be sold either directly to the consumer or to wholesalers.

The Persimmon Hill Berry Farm in Missouri (see **References**) offers an example of how a small entrepreneur can create and market a value-added mushroom product. Persimmon Hill developed a recipe for a shiitake mushroom sauce and invested in a commercial kitchen to produce it. The farm buys from local growers who, since the mushrooms are not for the fresh market, can freeze them until they have enough to make a delivery to the processing kitchen worthwhile. During warm weather, when production peaks, they can likewise freeze the shiitakes until Persimmon Hill needs them. These growers receive a better price than they would if they were selling at the lower, peak-season prices, and Persimmon Hill is ensured a steady supply for its sauce. Persimmon Hill sells its products on the Internet and through direct sales on the farm. (See [www.branson.com/persimmonhill/](http://www.branson.com/persimmonhill/).)

Drying shiitakes and other mushrooms is another way to add value and avoid the low prices of the peak season. For more on drying technologies, see the ATTRA publication *Options for Food Dehydration*. (After drying, mushrooms should be held at 0° F. for four days to kill any surviving pest eggs.)

## Financial Analysis

As a part of your market research, you need to do a financial analysis of the potential enterprise. Develop an enterprise budget with as much detail as you can provide. As with many farm enterprises, mushroom production is often only marginally profitable when labor and management costs are taken into consideration. An example of an enterprise budget for shiitake

Only by developing a market niche for a high-quality fresh product or by producing a mushroom-based food item can a small-scale beginner hope to compete.

## Case Study: Marketing Key for Small-Scale Growers

In the Ozarks of Missouri, Nicola MacPherson and her husband, Daniel Hellmuth, have grown shiitakes on three acres for nine years. The couple grow them the traditional way on oak logs, and they market them under the label Ozark Forest Mushrooms, which carries a USDA organic seal. To sell their mushrooms, however, they've relied on a variety of nontraditional marketing approaches. "To promote sales, you must be prepared to promote your product tirelessly," MacPherson says. Their principal markets are up-scale restaurants, catering companies, and gift catalogs. Customers who demand organic produce, such as CSA (Community Supported Agriculture) subscribers, also provide a reliable market.

MacPherson urges beginners to start modestly, learn the process thoroughly, and develop a small, reliable customer base—say, a half-dozen regular customers—as a foundation. (She offered free samples to help establish a local market.) She cautions new growers not to create a market demand that they cannot meet. Selling to supermarkets, for instance, can be fraught with problems, including the challenge of ensuring product freshness and the recurring need for educating new produce department employees. (Anon., 1998)

log production is available at <[www.ext.vt.edu/pubs/vegetables/438-898/shiitakemushrooms.pdf](http://www.ext.vt.edu/pubs/vegetables/438-898/shiitakemushrooms.pdf)>.

Using this format or a generic enterprise budget from Extension offices or off the Internet, fill it in with as many actual calculations and estimates of costs as you can. If you are considering several mushroom species, do a financial analysis of each one separately. Try to anticipate every cost so that you can construct an accurate financial picture. Include an educational and/or marketing component in your budget, allowing for free samples or flyers with information and recipes, especially if you are developing a new product or will be doing direct marketing.

If you are adding mushroom production to an integrated farming system, financial analysis is more difficult. Making a clear profit might not be as important as making use of off-season labor or the small logs from woodlot thinning to create a saleable product from what otherwise would have been waste.

## Further Resources

Two periodicals that include mushroom cultivation information are *The Mushroom Growers' Newsletter* and, to a lesser degree, *Mushroom the Journal*. Subscription information is included, along with citations for several key books, in the Resources section below. Web sites devoted to mushrooms and their cultivation are increasing every year. A selected list of mushroom Web sites is included below.

Some state or local mycological societies have groups interested in mushroom cultivation. To locate chapters in your area, contact the North American Mycological Association (see Resources).

## Conclusion

Commercial cultivation of mushrooms is not for everyone. It requires someone who is familiar with fungi life cycles and willing to commit time and money to research, designing a system, and developing a business. The mushroom cultivator must be able to carry out operations on time, be attentive to details, and be vigilant about pest invasions. In most cases, marketing requires excellent public relations skills.

Nevertheless, there is potential for an innovator who can use an existing facility, obtain a low-cost substrate, and produce a reliable supply of a high quality product. As part of a whole-farm system, mushrooms can augment productivity at any scale. Producing a nutritious food at a profit, while using materials that would otherwise be considered "waste," constitutes a valuable service in the self-sustaining community we might envision for the future. It is a challenge some will find worth taking.

## References

- Anon. 1998. Grower's business is 'mushrooming.' Small Farm Digest. Winter. p. 3.
- Anon. 2003. Small Farms Research News. Spring. p. 3.
- Arnold, Ralph. 1996. Grow fungi without the sterile trappings? Mushroom the Journal. Summer. p. 35.
- Beauséjour, Terri Marie. 1999. Mushrooms in the garden. Mushroom the Journal. Fall. p. 17-19.
- Cooner, Deanna. 2001. Mushroom farming. AgVentures. June-July p. 14-15.
- Edwards, Richard. 2000. The missing link? Mushrooms in permaculture. Permaculture Magazine. No. 25. p. 37-39.
- Garland, Franklin. 1996. Truffle Cultivation in North America. Garland Gourmet Mushrooms and Truffles, Inc., Hillsborough, NC. 41 p.  
Available for \$15 from:  
Garland Gourmet Mushrooms and Truffles, Inc.  
3020 Ode Turner Rd.  
Hillsborough, NC 27278  
919-732-3041  
919-732-6037 FAX  
truffleman@mindspring.com
- Green, Judy. 1988. Doing your own market research. Farming Alternatives. Cornell University Resource Sheet #6. November. 6 p.
- Hall, Ian R., G. Brown, and J. Byars. 1994. The Black Truffle. Rural Industries Research and Development Corporation. New Zealand. 107 p.
- Hardscrabble Enterprises, Inc.  
P.O. Box 1124 (or 617 N. Main St.)  
Franklin, WV 26807  
304-358-2921  
hardscrabble@mountain.net  
Contact: Paul Goland
- Park, Kwnag-ho. 2001. Nutritional Value of a Variety of Mushrooms. <[www.MushWorld.com/sub\\_en.html](http://www.MushWorld.com/sub_en.html)>. January. 5 p.
- Litchfield, Ken. 2002. In your yard: More than grass, shrubs and trees. Mushroom the Journal. Summer. p. 20-23.
- Ludmer-Gliebe, Susan. 1997. Sheep are essential to French truffle production. November. p. 4-5.
- Naegely, Stella K. 2000. Is there money in mushrooms? American Vegetable Grower. February. p. 40-43.
- Oei, Peter. 1991. Manual on Mushroom Cultivation. TOOL Foundation, Amsterdam. p. 49-50. (A new edition of this book is now available; see **Resources**.)
- Persimmon Hill Berry Farm  
RR 1, Box 220  
Lampe, MO 65681  
417-779-5443
- Royse, D.J. (ed.). 1996. Mushroom Biology and Mushroom Products: Proceedings of the Second International Conference, University Park, PA, June 9-12, 1996. Penn State, State Park, PA. 581 p.
- Royse, Daniel J., and Lee C. Schisler. 1980. Interdisciplinary Science Reviews. Vol. 5, No. 4. p. 324-331.
- Stamets, Paul. 2000-2001. A novel approach to farm waste management. Mushroom the Journal. Winter. p. 22. Or see at <<http://www.fungi.com/mycotech/farmwaste.html>>.
- Stamets, Paul. 1994. Permaculture with a mycological twist. The Permaculture Activist. May. p. 8-10.
- Stamets, Paul, and Jeff Chilton. 1983. The Mushroom Cultivator. Agarikon Press, Olympia, WA. 415 p.

# Appendix

## Mushroom Cultivation Media

| Growing Medium  | Mushroom Species  |  |
|---|---|--|
| Rice Straw  | Straw ( <i>Volvariella</i> )<br>Common ( <i>Agaricus</i> )  | Oyster ( <i>Pleurotus</i> )  |
| Wheat straw   | Oyster ( <i>Pleurotus</i> )<br>Stropharia   | Common ( <i>Agaricus</i> )<br>Straw ( <i>Volvariella</i> )                                 |
| Coffee pulp   | Oyster ( <i>Pleurotus</i> )   | Shiitake ( <i>Lentinus</i> )   |
| Sawdust   | Shiitake ( <i>Lentinus</i> )<br>Ear ( <i>Auricularis</i> )<br>Maitake ( <i>Grifola frondosa</i> )<br>Lion's Head or Pom Pom ( <i>Hericium</i> ) | Oyster ( <i>Pleurotus</i> )<br>Ganoderma ( <i>Reishi</i> )<br>Winter ( <i>Flammulina</i> ) |
| Sawdust-straw   | Oyster ( <i>Pleurotus</i> )   | Stropharia   |
| Cotton waste from textile industry                      | Oyster ( <i>Pleurotus</i> )   | Straw ( <i>Volvariella</i> )   |
| Cotton seed hulls                                       | Oyster ( <i>Pleurotus</i> )   | Shiitake ( <i>Lentinus</i> )   |
| Logs  | Nameko ( <i>Pholiota</i> )<br>White jelly ( <i>Tremella</i> )   | Shiitake ( <i>Lentinus</i> )   |
| Sawdust-rice bran                                       | Nameko ( <i>Pholiota</i> )<br>Shaggy Mane ( <i>Coprinus</i> )<br>Shiitake ( <i>Lentinus</i> )   | Ear ( <i>Auricularis</i> )<br>Winter ( <i>Flammulina</i> )                                 |
| Corncoobs   | Oyster ( <i>Pleurotus</i> )   | Shiitake ( <i>Lentinus</i> )   |
| Paper   | Oyster ( <i>Pleurotus</i> )   | Stropharia   |
| Horse manure (fresh or composted)                       | Common ( <i>Agaricus</i> )  |  |
| Crushed bagasse and molasses wastes from sugar industry | Oyster ( <i>Pleurotus</i> )   |  |
| Water hyacinth/Water lily                               | Oyster ( <i>Pleurotus</i> )   | Straw ( <i>Volvariella</i> )   |
| Oil palm pericarp waste                                 | Straw ( <i>Volvariella</i> )  |  |
| Bean straw  | Oyster ( <i>Pleurotus</i> )   |  |
| Cotton straw  | Oyster ( <i>Pleurotus</i> )   |  |
| Cocoa shell waste                                       | Oyster ( <i>Pleurotus</i> )   |  |
| Coir  | Oyster ( <i>Pleurotus</i> )   |  |
| Banana leaves   | Straw ( <i>Volvariella</i> )  |  |
| Distillers grain waste                                  | Lion's Head or Pom Pom ( <i>Hericium</i> )  |  |

## RESOURCES

### Periodicals

*The Mushroom Growers' Newsletter* is a monthly newsletter that contains cultivation information and current prices of mushrooms at San Francisco and New York markets.

Available for \$35/year from:  
The Mushroom Growers' Newsletter  
P.O. Box 5065  
Klamath Falls, OR 97601  
[www.mushroomcompany.com/](http://www.mushroomcompany.com/)

*Mushroom the Journal* is a quarterly publication that primarily contains information on foraging, with limited information on cultivation.

Available for \$19/year from:  
Leon Shernoff  
1511 E. 54th St.  
Chicago, IL 60615  
[www.mushroomthejournal.com/index.html](http://www.mushroomthejournal.com/index.html)

### Bibliography

The National Agricultural Library (NAL) has published several Quick Bibliographies (QBs), results of database searches on a given topic. QBs have been published for both shiitake and oyster mushrooms. They can be downloaded from the NAL Web site.

[www.nal.usda.gov/afsic/afspub.htm](http://www.nal.usda.gov/afsic/afspub.htm)

### Books

Stamets, Paul, and J.S. Chilton. 1983. *The Mushroom Cultivator*. Agarikon Press, Olympia, WA. 415 p.

*Includes growing parameters for 16 species and covers every aspect of mushroom cultivation.*

Available for \$29.95 from:  
Fungi Perfecti  
P.O. Box 7634  
Olympia, WA 98507  
800-780-9126 (toll-free) or 260-426-9292

Stamets, Paul. 1993. *Growing Gourmet and Medicinal Mushrooms*. Ten Speed Press. Berkeley, CA. 592 p.

*Companion volume to The Mushroom Cultivator. This third edition updates cultural and growing techniques, adds growing information on new varieties, and discusses strain selection for cultivation.*

Available for \$44.95 from Fungi Perfecti (See address above.)

Oei, Peter. 2003. *Manual on Mushroom Cultivation: Techniques, Species and Opportunities for Commercial Application in Developing Countries*. TOOL Publications, Amsterdam, The Netherlands. 274 p.

*First published in 1991, and now completely updated, this guide offers information on growing 12 species of mushrooms, with a particular emphasis on growing in developing countries. The manual includes 71 drawings, 93 photo illustrations.*

Available for \$53.50 plus \$8 for shipping from:

Western Biologicals, Ltd.  
P.O. Box 283  
Aldergrove, BC V4W2T8  
Canada  
604-856-3339 (telephone or FAX)  
[western@iprism.com](mailto:western@iprism.com) or [westernb@shaw.ca](mailto:westernb@shaw.ca)

Also available to developing countries from C-Point Publishers in the Netherlands. For ordering information, contact Ine Klerkx, <[ine.klerkx@cpoint.nl](mailto:ine.klerkx@cpoint.nl)>.

Hadeler, Hajo. 1995. *Medicinal Mushrooms You Can Grow*. The Cariaga Publishing House. 196 p.

*Excellent guide to wood-loving mushroom cultivation, from plugging old stumps to enriched sawdust culture in sterile bags. Covers medicinal species well. Well written and illustrated; index.*

Out of print, but some are still available from [amazon.com](http://amazon.com)

Hobbs, Christopher, and Michael Miovic (ed.). 1995. *Medicinal Mushrooms: An Exploration of Tradition, Healing and Culture*. Third

Edition. Botanical Press, Santa Cruz, CA.  
252 p.

*Mushroom toxicity, use in traditional medicine and in the human diet are supported by clinical studies and explorations of cultural influences in this technical coverage. More than 100 species of edible fungi are documented.*

Widely available for \$18.95.

## Associations

The North American Mycological Association (NAMA) publishes a bi-monthly newsletter, *The Mycophile*, and publishes an annual directory that provides names and addresses of all NAMA members and every mycology association in North America. NAMA focuses more on finding and identifying wild mushrooms than commercial cultivation.

Annual membership is \$35. Contact:  
NAMA  
336 Lenox Ave.  
Oakland, CA 94610-4675  
[www.namyco.org/](http://www.namyco.org/)

The American Mushroom Institute is a source of information on the mushroom industry. It serves mainly large, highly capitalized commercial producers.

AMI Washington DC Office  
One Massachusetts Avenue, N.W.  
Suite 800  
Washington, D.C. 20001  
202-842-4344  
[ami@mwmlaw.com](mailto:ami@mwmlaw.com)  
[www.americanmushroom.org](http://www.americanmushroom.org)

AMI Avondale Office  
1284 Gap Newport Pike  
Suite 2  
Avondale, PA 19311  
610-268-7483  
[MushroomNews@kennett.net](mailto:MushroomNews@kennett.net)

## Web sites

[Note that addresses may change. A search of the Web should provide current locations.]

### How to Grow Mushrooms

[www.gov.ns.ca/nsaf/elibrary/archive/hort/organic/990015.htm](http://www.gov.ns.ca/nsaf/elibrary/archive/hort/organic/990015.htm)

*From the Nova Scotia Department of Agriculture and Fisheries, this Web page offers a good overview of growing mushrooms in compost.*

### The Mushroom Council: Six Steps to Mushroom Farming

[www.mushroomcouncil.org/production/six-steps.htm](http://www.mushroomcouncil.org/production/six-steps.htm)

*From the Pennsylvania State University Agriculture Extension Service, this page describes step by step phase I composting, phase II composting, spawning, casing, pinning, and cropping.*

### Permaculture with a Mycological Twist: The Stametsian Model for a Synergistic Mycosphere

[www.fungi.com/mycotech/permaculture.html](http://www.fungi.com/mycotech/permaculture.html)

*This article carried on the Fungi Perfecti Web site describes permaculture applications for mushrooms. (See the sidebar.)*

### Mush-World

[www.mushworld.com/home/](http://www.mushworld.com/home/)

*"Total mushroom information" is the banner claim here. This excellent resource features sections on cultivation, pests and disease, and medicinal mushrooms, as well as the monthly webzine Mushworld. Requires free registration for access. Highly recommended.*

### Penn State Mushroom Spawn Laboratory

[MushroomSpawn.cas.psu.edu/](http://MushroomSpawn.cas.psu.edu/)

*A comprehensive Web site with resources on mushroom science and cultivation.*

### Gourmet Mushrooms

[www.arrowweb.com/MUSHROOM/](http://www.arrowweb.com/MUSHROOM/)

*Source of mushroom kits and mushroom nutraceuticals; extensive bibliography on the medicinal value of mushrooms (<[www.gmushrooms.com/Healthref.html](http://www.gmushrooms.com/Healthref.html)>).*

### Fungal Jungal: Western Montana Mycological Society

[www.fungaljungal.org](http://www.fungaljungal.org)

*A good example of a regional mycological society Web site filled with diverse resources, including information on morels, fire ecology, a western mushroom photo guide, and recipe lists.*

The Mushroom Council  
[www.mushroomcouncil.org/](http://www.mushroomcouncil.org/)

*Home of the mushroom industry's marketing council, this site contains useful information about consumer buying trends and providing for food service needs, as well as nutritional and production information; focuses mainly on *Agaricus* spp. with no specialty mushroom differentiation.*

## Resources (shiitake)

### Bibliography: shiitake

Rafats, Jerry. 1996. Shiitake: Cultivated Mushroom. Quick Bibliography Series B:90-4. National Agricultural Library, Beltsville, MD.

*A bibliography of articles on shiitake mushrooms. Though somewhat dated (published in 1996), this collection still contains valuable information for shiitake producers. It's available on-line at <[www.nal.usda.gov/afsic/AF-SIC\\_pubs/qb9613.htm](http://www.nal.usda.gov/afsic/AF-SIC_pubs/qb9613.htm)>.*

### Books: shiitake

Harris, Bob. 1994. Growing Shiitake Commercially. 2nd Ed. Science Tech Publishers, Madison, WI. 72 p.

*Large-scale cultivation of shiitake mushrooms using traditional oak logs. Based on many years' work, including material from recent visits to Japan. Some of the most modern and cost-effective methods are presented with photographs and drawings.*

Available from Mushroompeople (See **Suppliers**).

Kozak, M.E., and J. Krawczyk. 1993. Growing Shiitake Mushrooms in a Continental Climate. 2nd Ed. Field & Forest Products, Peshtigo, WI. 114 p.

*Describes step-by-step year-round shiitake cultivation, from log inoculation to fruiting.*

*Excellent reference for inland producers*

Available for \$17.50 postage paid from Field & Forest Products, Inc.  
(See Suppliers.)

Przybylowicz, Paul, and John Donoghue. 1990. Shiitake Growers Handbook. Kendall/Hunt Publishing Co., Dubuque, IA. 217 p.

*Book covers a wide range of topics, from log cultivation to sawdust cultivation. Information includes both scientific material and practical advice. Emphasis is on presenting as much information as possible rather than selectively choosing the best or most advanced methods.*

Widely available for \$25.

Jones, Kenneth. 1995. Shiitake: The Healing Mushroom. Healing Arts Press, Rochester, VT. 128 p.

[www.parkstpress.com/titles/shiita.htm](http://www.parkstpress.com/titles/shiita.htm)

*This book describes the nutritional benefits and traditional uses in Chinese medicine for shiitake mushrooms. Chapters cover shiitakes used in folk medicine for controlling cholesterol, cancer prevention, treating viruses and chronic fatigue syndrome.*

Widely available for \$9.95.

### Web sites: shiitake

The Ohio State University Extension Office features a series of on-line fact sheets that detail shiitake cultivation.

- Shiitake Mushroom Production: Introduction and Sources of Information and Supplies  
<http://ohioline.osu.edu/for-fact/0039.html>
- Shiitake Mushroom Production: Obtaining Spawn, Obtaining and Preparing Logs, and Inoculation  
<http://ohioline.osu.edu/for-fact/0040.html>
- Shiitake Mushroom Production: Logs and Laying Yards  
<http://ohioline.osu.edu/for-fact/0041.html>
- Shiitake Mushroom Production: Fruiting, Harvesting and Crop Storage  
<http://ohioline.osu.edu/for-fact/0042.html>

- Shiitake Mushroom Production: Economic Considerations  
<http://ohioline.osu.edu/for-fact/0043.html>

#### Growing Shiitake Mushrooms

<http://osueextra.com/pdfs/F-5029web.pdf>

*From the Oklahoma Cooperative Extension Service, this factsheet offers an overview of shiitake cultivation suitable to hardwood forests of east and central Oklahoma.*

## Spawn and Equipment Suppliers

[This list is not comprehensive and does not imply endorsement of these companies.]

Amycel Spawn  
P.O. Box 560  
Avondale, PA 19311  
800-795-1657 or 800-995-4269 (toll-free)  
[www.amycel.com](http://www.amycel.com)

Choice Edibles  
584 Riverside Park Road  
Carlotta, CA 95528  
707-768-3135  
[www.choiceedibles.com](http://www.choiceedibles.com)

CropKing  
5050 Greenwich Road  
Seville, OH 44273-9413  
330-769-2002  
330-769-2616 FAX  
[www.cropking.com/mushroom.shtml](http://www.cropking.com/mushroom.shtml)

Field & Forest Products  
N3296 Kozuzek Rd.  
Peshtigo, WI 54157  
800-792-6220 (toll-free)  
[www.fieldforest.net](http://www.fieldforest.net)

Fungi Perfecti  
P.O. Box 7634  
Olympia, WA 98507  
260-426-9292  
[www.fungi.com](http://www.fungi.com)

Garden City Fungi  
P.O. Box 1591  
Missoula, MT 59806  
406-626-5757  
[www.gardencityfungi.com](http://www.gardencityfungi.com)

Gourmet Mushroom Products  
P. O. Box 515 IP  
Graton, CA 95444  
707-829-7301  
707-823-9091 FAX  
[www.gmushrooms.com/pots/](http://www.gmushrooms.com/pots/)

Hardscrabble Enterprises, Inc.  
P.O. Box 1124 (or 617 N. Main St.)  
Franklin, WV 26807  
304-358-2921  
[hardscrabble@mountain.net](mailto:hardscrabble@mountain.net)  
Contact: Paul Goland

L.F. Lambert Spawn Co.  
1507 Valley Rd.  
Coatesville, PA 19320  
610-384-5031

Long Ridge Farms  
406 Tom Cook Rd.  
Sugar Grove, NC 28679  
828-297-4373

Mushroompeople  
P.O. Box 220  
560 Farm Rd.  
Summertown, TN 38483  
931-964-2200  
[www.thefarm.org/mushroom/mpframe.html](http://www.thefarm.org/mushroom/mpframe.html)

Myco Supply  
P.O. Box 16194  
Pittsburgh, PA 16237  
800-888 0811 (toll-free)  
[www.MycoSupply.com/](http://www.MycoSupply.com/)

Northwest Mycological Consultants  
702 NW 4th St.  
Corvallis, OR 97330  
541-753-8198  
[NMC@nwmycol.com](mailto:NMC@nwmycol.com)

Sylvan Spawn Laboratory  
West Hills Industrial Park

Kittanning, PA 16201  
800-323-4857 (toll-free) or 724-543-2242

J.B. Swayne Spawn Co.  
P.O. Box 618  
Kennett Square, PA 19348  
610-444-0888

UNICORN Imp. & Mfg. Corp.  
113 Highway 24  
Commerce, Texas 75429 USA  
800-888-0811 (toll-free)  
UNICORNbag@aol.com  
www.unicornbags.com

Western Biologicals, LTD.  
P.O. Box 283  
Aldergrove, BC V4W2T8  
CANADA  
604-856-3339  
westernb@shaw.ca

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