Growing Shiitake Mushrooms

Oklahoma Cooperative Extension Service • Division of Agricultural Sciences and Natural Resources

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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 Wangenh.) 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 threadlike 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.

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

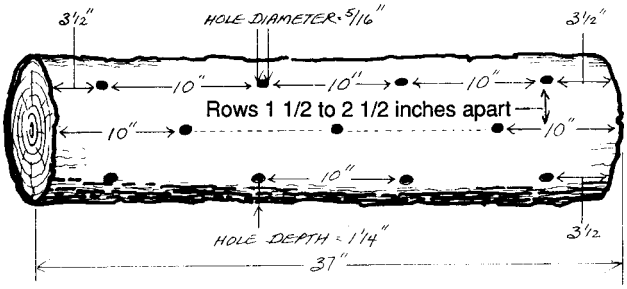


Figure 1. One possible technique for preparing logs for inoculation

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.

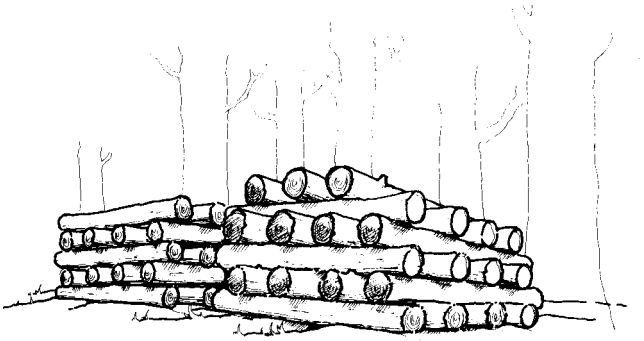
Shiitake can also be grown under greenhouse conditions. By controlling temperature and humidity conditions, logs can be forced to produce during the winter and summer when outside logs are not fruiting. These producers can take advantage of the best markets. Some experienced growers also grow shiitake 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

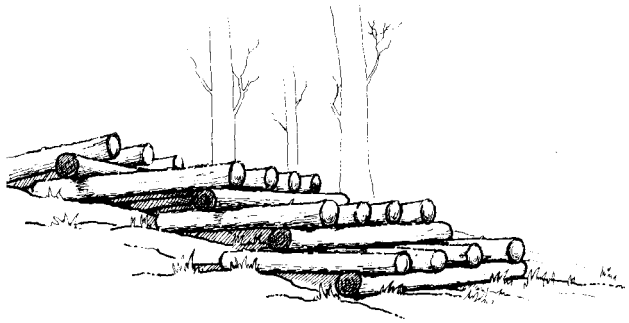
Mushrooms should be harvested on a daily basis, usually in the afternoon when the mushrooms are dry. Mushrooms are removed from the log by twisting or cutting at the base when they have opened about 60 to 75 percent. They should be put immediately into cardboard boxes and refrigerated. Refrigeration 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 90oF is gradually increased to 140oF over a 10 to 14 hour period. Seven pounds of fresh shiitake yields about one pound of dried mushrooms.

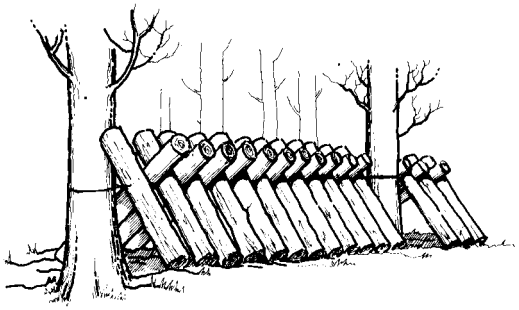
For most growers, direct, local marketing is probably the best marketing option. Many people are still unaware of this mushroom as a new food option. In most cases, some education about the qualities of shiitake will be required.



Criss-Cross Method



Stacking Method on Slope or Hill



X Pattern Method

Figure 2. Common stacking methods.

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.

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

	Logs		Mushrooms			
Year	Number at Beginning of Year	Percent Loss1	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

1Loss 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:[1]															
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	2691	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:[1]															
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	173095	213584	255636	299783	357098	405533	424241
After Taxes:[2]															
PERIOD NET REVS.	-21570	-13390	7769	23976	24626	25730	26474	19681	28953	29608	30594	32021	43279	35741	13817
CUM NET REVENUE	-21570	-34960	-27191	-3214	21411	47141	73615	93296	122250	151857	182451	214472	257751	293492	307309

[1]All values are in dollars inflated at 4 percent to year of occurrence, before taxes. Columns may not add due to rounding error.
[2]All values are in dollars inflated at 4 percent of occurrence, after taxes. Columns may not add due to rounding error.

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.

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