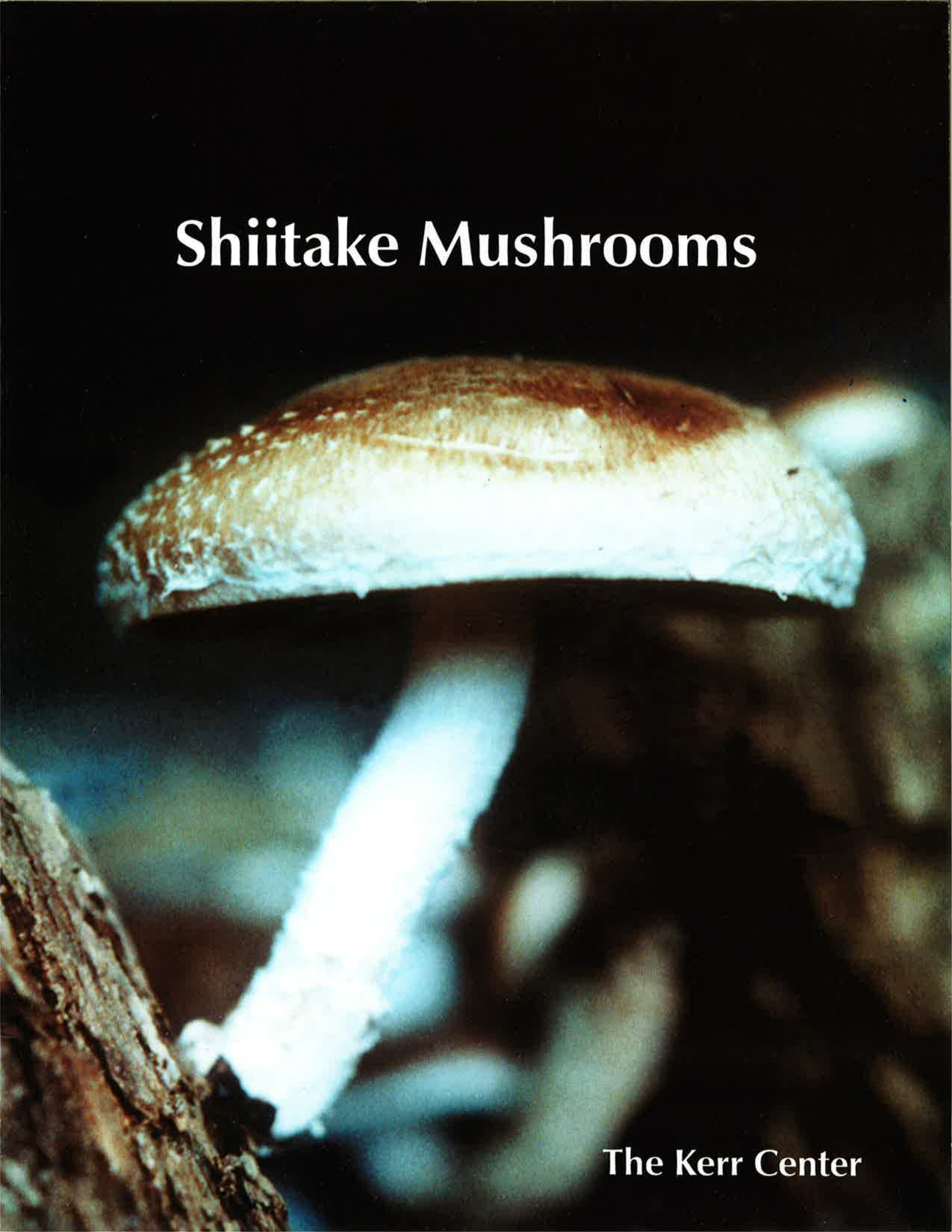
Shiitake Mushrooms



The Kerr Center

Shiitake Mushrooms

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The Kerr Center for Sustainable Agriculture, Inc. strives to find ways of sustaining our world rather than exhausting the precious natural resources that are vital to future generations. The Kerr Center provides leadership, technical assistance, education, market development, and limited financial assistance and planning to farmers who seek ecological and economical methods of producing food and fiber. Our goal is to strengthen rural communities and to support efforts to make our world more ecologically secure. Written material in this publication may be reprinted if proper credit is given, and a copy is sent to the Kerr Center.

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The name, shiitake, is taken from the Shii tree, one of the species that it grows on in nature, and "take," a Japanese word for mushroom. It originated in China during the Sung Dynasty in 960 A.D.

The shiitake is the second most cultivated mushroom in the world behind the white button. Shiitake mushrooms were banned from the United States until 1972 when scientists from the United States Department of Agriculture discovered they had mistook shiitake's Latin name, *Lentinula edodes*, for the fungus that attacks railroad ties, *Lentinula lepideus*.

Shiitake mushrooms have a chewy texture and a full–bodied aromatic flavor. Nutritionally mushrooms compare favorably with most fresh vegetables in protein content and are good sources of vitamins, such as riboflavin, and minerals, such as copper and iron. They are low in calories (125 per fresh pound) and low in fat. They retain their nutrients well during cooking, canning, dehydrating, and freezing. Shiitakes have also been reported to have a number of beneficial health effects and certain medicinal uses.

Selecting and Cutting Logs

Shiitake can be grown either on logs or on a special combination of oak sawdust, bran, millet, and other additives. Most small–scale farmers will want to inoculate logs because they require less environmental control.

The most common tree species used are from the oak family, although any of the hardwoods will work. The reason oak is the most commonly used tree is that the density of the wood and strong bark protect the shiitake from exposure. Some growers believe sweetgum produces better than oak but have experienced problems with the bark. During the spawn run, the mycelium colonized the sweetgum so fast the bark tended to split. Until further information is available, sweetgum should be used cautiously. Softwoods, such as elm, should not be used.

Trees should be cut using a timber improvement method. Cutting trees that are trapped in the understory of larger trees, and thinning in such areas reduces competition for the remaining trees. We believe that using a selective cutting method for timber improvement preserves the forest for future use.

It is important to cut a live tree, free from any obvious insect or disease problems. Trees are cut when logs are green and the sap is down. During this dormant stage, the tree's immune system is diminished. This occurs after the first freeze of autumn and lasts until the trees start budding. In eastern Oklahoma, that time period runs from November through February.

The ideal log has a large amount of sapwood and a small section of heartwood. Sapwood is the outer portion of wood that lies between the bark and heartwood (Figure 1). It is responsible for transporting nutrients between the roots and canopy and back again. Sapwood contains a high concentration of the sugars and elements critical for good shiitake growth.

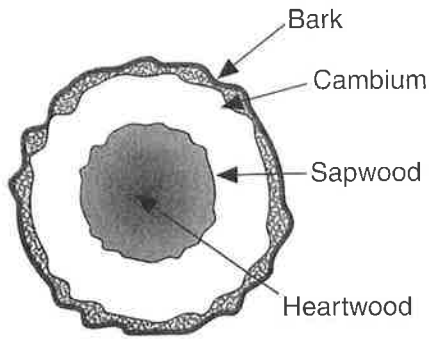

Figure 1. Interior view of a log.

Logs used for shiitake production usually average 4 to 6 inches in diameter and 40 inches in length. This allows for easy log handling. Length can be adjusted for personal preference. Based on our experience, a diameter of more than 6 inches makes handling difficult.

Do not drag logs on the ground after they have been cut. Torn bark can allow other organisms to enter the log and compete with the shiitake. The logs will be more susceptible to fungi problems if dragged through the forest instead of carried. If you purchase cordwood from a pulpwooder, make sure he understands this point.

Inoculation

Logs should be inoculated from one to three weeks after cutting to ensure the optimal moisture content.

Several tools are needed to inoculate logs. A drill, drill bit, spawn plunger, turkey baster, wax heater, labels, and staple gun. There are specific drills for inoculating, but the majority of these are expensive tools designed for large operations. A $\frac{3}{8}$-inch drill that turns 2,100 rpm is suitable for growers. At the Kerr Center, we have tried several brands and strongly recommend Makita™.

Several growers have made specialized drill bits out of ordinary ones by welding washers as stops. A converted drill bit may be fine for a few logs, but for 50 logs or more, we suggest buying an auger–type drill bit with a stop. It will drill the correct depth of $\frac{5}{8}$ inch and width of $\frac{1}{2}$ inch in 300 to 500 logs before burning up. This drill bit may be purchased from companies that sell spawn.

The most popular drilling pattern is referred to as a "Diamond" pattern (Figure 2). Holes are drilled starting 3 inches from the end of the log, every 6 inches down the length of the log. The next row should begin 3 inches from the first row at the end of the log with holes drilled every 6 inches. This pattern is continued around the whole log. The result will be rows of drilled holes, staggered to form a diamond pattern. For example, a log with a 4-inch diameter should have approximately 54 holes. Although it is not necessary to be exact, a log with too many holes may produce small or

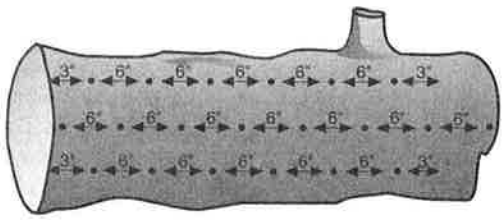

Figure 2. Example of a diamond drilling pattern.

disfigured mushrooms. This can best be compared to fruit tree production. Peach growers normally remove some fruit from a tree, which allows the remaining peaches to grow larger.

After drilling, spawn is placed in the holes. The spawn or mycelium is the mass of threads which forms the vegetative feeding part of the shiitake. The mycelia is either grown out on wooden pegs called "plug" or "dowel spawn" or on supplemented sawdust called "sawdust spawn." Sawdust spawn is more economical when inoculating more than 50 logs.

Always check the spawn as soon as it arrives to make sure it is alive and fresh. Good quality spawn is white (sometimes with a brown crust) and smells like fresh mushrooms.

The inoculation tool is a thumb or palm plunger with a tube to hold the sawdust (Figure 3). The tool is forced into the sawdust spawn in order to fill the tube. Then the tool is placed over a hole, the plunger is pressed to insert the mixture, and given a twist to ensure that it is tightly packed.

Figure 3. Example of a thumb plunger.

Once in a hole, the spawn must be protected from moisture loss through the inoculation site. Wax is melted to a temperature of 300°F and dripped over the hole to form a seal. Cheese wax is preferred because it adheres well and remains intact. Since cheese wax is an expensive input, a mixture of one-half cheese wax and one-half paraffin can also be applied. Although paraffin slides off when applied by itself, mixing it with the cheese wax works well.

A turkey baster is used to apply the wax. In order to keep an excessive amount of wax from running out of the baster, a cut–off nail is placed in the end (Figure 4). The nail acts as a valve controlling the flow of the wax. Simply touch the tip of the nail to the inoculation site and it retreats up into the baster allowing a small stream of wax to cover the hole.

The most effective inoculation system uses four people. A table is used to hold the logs in place while working. One person drills at the end of the table, two inoculate in the middle, and one seals holes at the other end and stacks the logs. This procedure reduces the time and labor needed to pick up logs repeatedly. Four people can inoculate about 200 logs in six hours after a few days of practice. Logs are only inoculated once in their fruiting life cycle.

Figure 4. Example of a turkey baster with cut-off nail in the end.

The final step is to label the logs. Aluminum tags can be attached with a staple gun on the end of each log to record the strain and inoculation date. Paint is also a good method. Labeling allows a producer to record the production data on different strains.

After inoculating the logs, they should be laid outside in a crib stack (Figure 5). They now enter a stage referred to as the spawn run which lasts for 6 to 12 months. Logs should be placed under trees that provide 60 percent shade. Shadecloth or burlap could also be used for shading. Moisture is also conserved when the logs are covered. A good spawn run requires a moisture level between 40 and 60 percent. After seven months, the logs should be restacked every four weeks until fruiting. In a crib stack design, the spawn tends to grow into the surrounding logs, acting like an adhesive. By rotating the logs every four weeks, the spawn does not have time to adhere to another log.

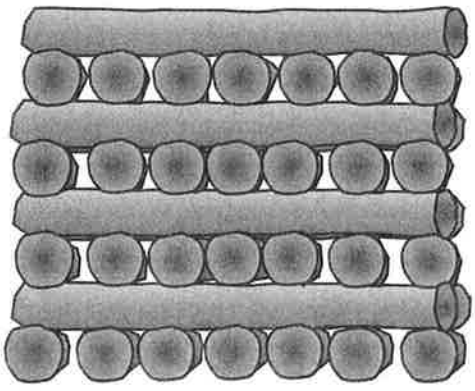

Figure 5. Seven rows of seven logs are laid north to south and west to east alternately with one log placed across the top.

Before fruiting begins, logs are placed in an A-frame configuration.

Fruiting

Mushroom production begins after the shiitake fungus colonizes the log. The first fruiting will normally occur 6 to 18 months after inoculation.

Numerous strains of shiitake are available and are classified as cold weather, warm weather, or wide range depending on when they produce mushrooms. When purchasing spawn, it is best to order at least two strains. This enables a producer to extend the growing season. Cold weather strains fruit between 40° to 65°F, warm weather between 50° to 80°F, and wide range between 40° to 80°F.

The Kerr Center conducted a demonstration to evaluate the performance of nine different spawn varieties. Each variety was used to inoculate 100 logs. After harvesting, the mushrooms were weighed from each group (Table 1). The best varieties were Westwind, WR85, V3, and CW25. Strains that gradually increase in yield are preferred due to marketing advantages.

Shiitake production occurs on a bell-shaped curve. It builds for two to three years, then decreases as the logs deteriorate. This fluctuation can influence marketing. It is important to inoculate new logs every year, thus ensuring a steady yield as old logs cease production.

Monitoring and maintaining proper environmental conditions is important in the production process. The best growing conditions occur when the temperature is maintained between 70 and 85 degrees, log moisture content is about 60 percent, and humidity is between 80 and 85 percent. During summer months, logs also require 60 percent shade. A yard sprinkler or irrigation system with misters set on a time clock can be used to keep the moisture constant depending on the grower's situation. It can also cool logs on hot, summer days.

At the Kerr Center, we used two impact-type sprinkler heads set on a three-hour timer to moisten 1,000 logs twice a week during warm weather. The optimum situation is when the bark remains dry but the inside is wet. Avoid overwatering. This will cause a log to rot at a faster rate and encourages competing fungi.

There are two types of fruiting, natural and forced. Natural fruiting is usually employed by outside operations in the shade of trees or a shadecloth. Fruiting can happen twice in the spring and twice in the fall if temperatures are in the optimum range. However, most growers do not depend on nature for the rainfall needed to initiate fruiting. Instead a sprinkler is used to supply the needed moisture. Natural fruiting is less expensive, but only allows you a certain marketing period.

Forced fruiting occurs in an indoor or outside operation. Logs are soaked in either cool or warm water, depending on the strain, for 24 hours. After soaking, mushrooms usually appear in three to ten days if the temperature is correct. This allows a grower to maintain some control of fruiting. However, logs must rest six weeks between cycles.

The quantity of mushrooms produced from a log is directly related to the biomass of the log. A log will last four to five years and yield 3¾ pounds of mushrooms under natural

Table 1. A comparison of the pounds of mushrooms produced per log with nine shiitake spawns.

Spawn	Strain	Spawn run	1990	1991	1992	1993
Westwind	WR	9 months	0 lb	¾ lb	1 lb	1 lb
WR46	WR	8 months	0 lb	½ lb	¾ lb	1 lb
WR85	WR	10 months	0 lb	⅓ lb	1 lb	1 lb
WW44	WW	14 months	0 lb	¼ lb	½ lb	½ lb
WW70	WW	NA	0 lb	0 lb	0 lb	0 lb
V-3	WW	10 months	0 lb	½ lb	1½ lb	1 lb
Twice Flower	CW	18 months	0 lb	0 lb	⅓ lb	¾ lb
CW25	CW	11 months	0 lb	½ lb	1 lb	¾ lb
Snowcap	CW	14 months	0 lb	½ lb	¾ lb	1 lb

WR = Wide Range, WW = Warm Weather, CW = Cold Weather

fruiting. With forced fruiting, the biomass is consumed faster, and 3¾ pounds of mushrooms are produced in two to three years.

The spawn run is nearly complete when white blotches appear at the ends of the logs indicating the mycelium has colonized the logs. A white bump may show up on the inoculation site. This is called pinning. A stray mushroom also indicates the end of the spawn run. At this time, logs should be stacked in an A–frame to allow mushrooms to grow without touching each other to prevent deformity.

Harvesting and Storage

After fruiting begins, logs should be checked twice a day. A #1-grade mushroom has a one- to two-inch cap, three-quarters of the way open. A small lip can be felt on the edge of the mushroom. Shiitakes are brown and have slightly felty caps and white gills that are eroded, meaning each gill has a rough edge. Mushrooms are removed from the logs by cutting the base of the stem with a knife or by twisting the base of the stem with your hand.

After harvesting, fresh shiitakes have a shelf life of four days. Refrigeration can extend the shelf life for up to two weeks. If shipping overnight, keep the mushrooms unrefrigerated until after they arrive at their final destination.

If shiitakes are marketed as dried mushrooms, they should be placed over dry warm air, preferably sunlight which increases their vitamin D content. Seven pounds of fresh mushrooms yields about one pound of dried mushrooms.

Table 2. Ten-year yield projection for a small-scale shiitake mushroom operation.

	No. of Logs Inoculated	No. of Logs Fruiting	Yield (Pounds)
	500		
Year 1	750	450	167
Year 2	1,007	707	432
Year 3	1,255	955	786
Year 4	1,497	1,197	903
Year 5	1,332	1,032	778
Year 6	1,332	1,032	778
Year 7	1,332	1,032	778
Year 8	1,332	1,032	778
Year 9	1,332	1,032	778
Year 10	1,332	1,032	778

Yield projections are calculated using the assumptions in Table 3.

Marketing

Shiitake mushrooms are sold by weight. A scale is necessary to weigh shiitakes before they are packaged. If you are selling mushrooms directly, the scale may require certification by the State Department of Agriculture. Call your state agency and inquire about any regulations concerning your operation. Some form of packaging will also be necessary for marketing your product.

Volume, location, quality, and available time are some of the factors to consider when developing a marketing strategy. The most important marketing tool for shiitake growers is consumer education. Little documentation is available to the general public on storage, handling, and preparation techniques. Promotional items, such as recipe cards, have several advantages.

Small–scale growers may have more success in local markets. Supermarkets, health food stores, restaurants, farmers' markets, roadside stands, and on-farm sales are examples of direct marketing opportunities. Transportation can be a disadvantage for growers selling to restaurants and grocery stores. Costs may be high depending on the size and locations of the outlets.

Nondirect marketing alternatives include wholesalers, brokers, and cooperatives. A wholesaler is an individual or business firm who purchases large quantities of produce for resale and distribution. A broker acts as an agent for the buyer or seller. Most wholesalers and brokers prefer to deal with large-scale growers who can provide a steady supply of mushrooms during the year. Cooperatives are formed when there are several small- to mid–sized growers of one or several related crops in one area. Marketing efficiency can be enhanced through a cooperative by providing greater total volume.

Pests

Logs and mushrooms are both susceptible to pests and disease. Good management skills can correct most problems. The use of chemicals or traps to eradicate pests is not necessary.

Common pests of mushrooms include mice, deer, squirrels, birds, and moles. The only pest encountered at the Kerr Center is mice. Although mice usually only take one bite out of a mushroom, the shiitake becomes marred and cannot be sold. Since this loss represents a small percentage of our production, no control measures are taken. The other animals listed present the same threat. If production loss is high, consider placing a protective barrier around or over the laying yard.

Logs must also be closely observed for any indication of termites. This occurs most often when logs are in direct contact with bare ground. Our experience has shown termites appear more often when logs are placed beneath pine trees. Some growers cover the laying yard with plastic to help avoid this problem.

Table 3. Assumptions for ten-year budget projection for a small-scale shiitake mushroom operation.

1. The producer provides all labor.
2. Mushrooms are produced for 10 years.
3. Outdoor, natural fruiting techniques are used.
4. The producer purchases a chainsaw and cuts the logs.
5. The logs cost $40 per cord.
6. There are 318 logs per cord (98 six-inch and 220 four-inch logs, 40 inches long).
7. Start with 500 logs the first year and add 300 logs per year from years two through ten.
8. Borrow money for start-up costs at 9% (amount borrowed depends on size of initial operation.)
9. Log loss is 10% the first year and 3% for the next three years (Anderson and Marcouiller, 1990).
10. Each log produces a total of 3.04 pounds of mushrooms over a four-year fruiting life expectancy.
11. Grades of mushrooms: 65% are sold as #1's at $4.50/lb; 25% are sold as #2's at $3.50/lb; and 10% are culled (no value).
12. All mushrooms are marketed fresh.
13. Half of the mushrooms are marketed locally and the other half are shipped to Dallas, Texas; Oklahoma City, Oklahoma; and Little Rock, Arkansas.

Costs and Returns

Shiitake mushroom production can be a valuable enterprise alone or as an alternative income source to an existing farm operation. New growers should always start small to minimize risk during the beginning years. After four years, you should acquire ample experience with production and marketing techniques. At this time, you may want to reevaluate your management plan and either increase or decrease production.

At the Kerr Center, we developed a ten-year management plan that should provide a positive period net revenue in the second year and a positive cumulative net revenue in the fourth year. Shiitake production in our recommendation involves inoculating 500 logs the first year and 300 logs for each of the following years.

Conclusion

The low labor requirement for shiitake production suits the needs of producers interested in alternative enterprises, and the start-up cost is within reach of most farmers. Marketing is the major obstacle. Although markets are available, each is usually small, such as health food stores, gourmet restaurants, or food cooperatives. A prospective grower needs to spend some time contacting each distributor. Several businesses may only place a small order, so the grower needs many outlets to support production.

Shiitake mushrooms are like other alternative enterprises in agriculture. A person must develop good management practices and marketing skills and have a desire to succeed.

Table 5. Ten-year labor requirement projection (hrs./yr.) for a small-scale shiitake mushroom operation.

		Size of Operation	
	Year	500	1,000
Cut Logs	1	32	64
	2 - 10	11	19
Inoculation	1	96	192
	2 - 10	34	58
Water	1 - 10	7	9
Marketing	1 - 3	40	40
	4 - 10	24	24
Harvest	1 - 10	8	16
Total	1	183	305
	2 - 3	100	142
	4 - 10	84	126

Labor requirements are calculated using the assumptions in Table 3.

Table 4. Ten-year budget projection for a small-scale shiitake mushroom operation.

No. of Logs	500	300	300	300	300	300	300	300	300	300
No. of Cords	1.57	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Years	1	2	3	4	5	6	7	8	9	10
Fixed Expenses										
Drill (Makita 2100, 3/8)	54									
Inoculation Tool ($22/tool)	44									
Wax Heater	29									
Chain Saw	300									
Scale	120									
Staple Gun	12									
Water Hose	35									
Sprinkler	8									
Total Fixed Expenses	602									
Variable Expenses										
Cordwood	63	38	38	38	38	38	38	38	38	38
Inoculum ($16/bag)	192	115	115	115	115	115	115	115	115	115
Wax ($75/case)	38	23	23	23	23	23	23	23	23	23
Drill Bits ($10/bit)	20	12	12	12	12	12	12	12	12	12
Turkey Baster	5	3	3	3	3	3	3	3	3	3
Metal Labels	23	14	14	14	14	14	14	14	14	14
Irrigation Cost	25	38	50	63	75	67	67	67	67	67
Marketing	200	200	200	120	120	120	120	120	120	120
Packaging	0	22	56	102	117	101	101	101	101	101
Shipping	0	46	120	218	251	216	216	216	216	216
Subtotal (Fixed and Variable Expenses)	1,167	510	630	707	767	708	708	708	708	708
Interest on Start-up Expenses (9%)	105	46	57							
Total Expenses (Fixed, Variable, and Interest)	**1,273**	**555**	**687**	**707**	**767**	**708**	**708**	**708**	**708**	**708**
Total Revenue		**633**	**1,640**	**2,986**	**3,432**	**2,958**	**2,958**	**2,958**	**2,958**	**2,958**
Period Net Revenue (or Return to Land, Labor, and Management)	-1,273	77	953	2,279	2,665	2,250	2,250	2,250	2,250	2,250
Cumulative Net Revenue	**-1,273**	**-1,195**	**-242**	**2,037**	**4,702**	**6,952**	**9,201**	**11,451**	**13,701**	**15,950**

A #1-grade shiitake mushroom.

References

Anderson, Steve and Dave Marcouiller. 1990. Growing shiitake mushrooms. OSU Ext. Facts No. 5029. Oklahoma State Univ. Ext. Serv., Stillwater, OK.

Resource List

Books/Newsletters

Alternative Methods of Shiitake Inoculation
Bob Harris
Mushroompeople
P.O. Box 220
Summertown, TN 38483-0220
(615) 964-2200

Growing Shiitake Commercially
Bob Harris
Mushroompeople
P.O. Box 220
Summertown, TN 38483-0220
(615) 964-2200

From Harvest to Hearth
M.E. Kozak and J. Krawczyk
Field and Forest Products, Inc.
N3296 Kozuzek Road
Peshtigo, WI 54157
(715) 582-4997

Growing Shiitake Mushrooms in a Continental Climate
M.E. Kozak and J. Krawczyk
Field and Forest Products, Inc.
N3296 Kozuzek Road
Peshtigo, WI 54157
(715) 582-4997

Shiitake Growers Handbook: The Art and Science of Mushroom Cultivation
P. Przybylowicz and J. Donaghue
Northwest Mycological Consultants, Inc., Dept. S.
702 NW 4th Str.
Corvallis, OR 97330
(503) 753-8198

Shiitake News
Forest Resource Center
Rt. 2, Box 156A
Lanesboro, MN 55949
(507) 467-2437

Spawn and Equipment Suppliers

Field and Forest Products, Inc.
N3296 Kozuzek Road
Peshtigo, WI 54157
(715) 582-4997

Fungi Perfecti
P.O. Box 7634
Olympia, WA 98507
(206) 426-9292

Mushroom Inc.
P.O. Box 69
Charlotte Court House, VA 23923
(804) 736-8311

Mushroompeople
P.O. Box 220
Summertown, TN 38384
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