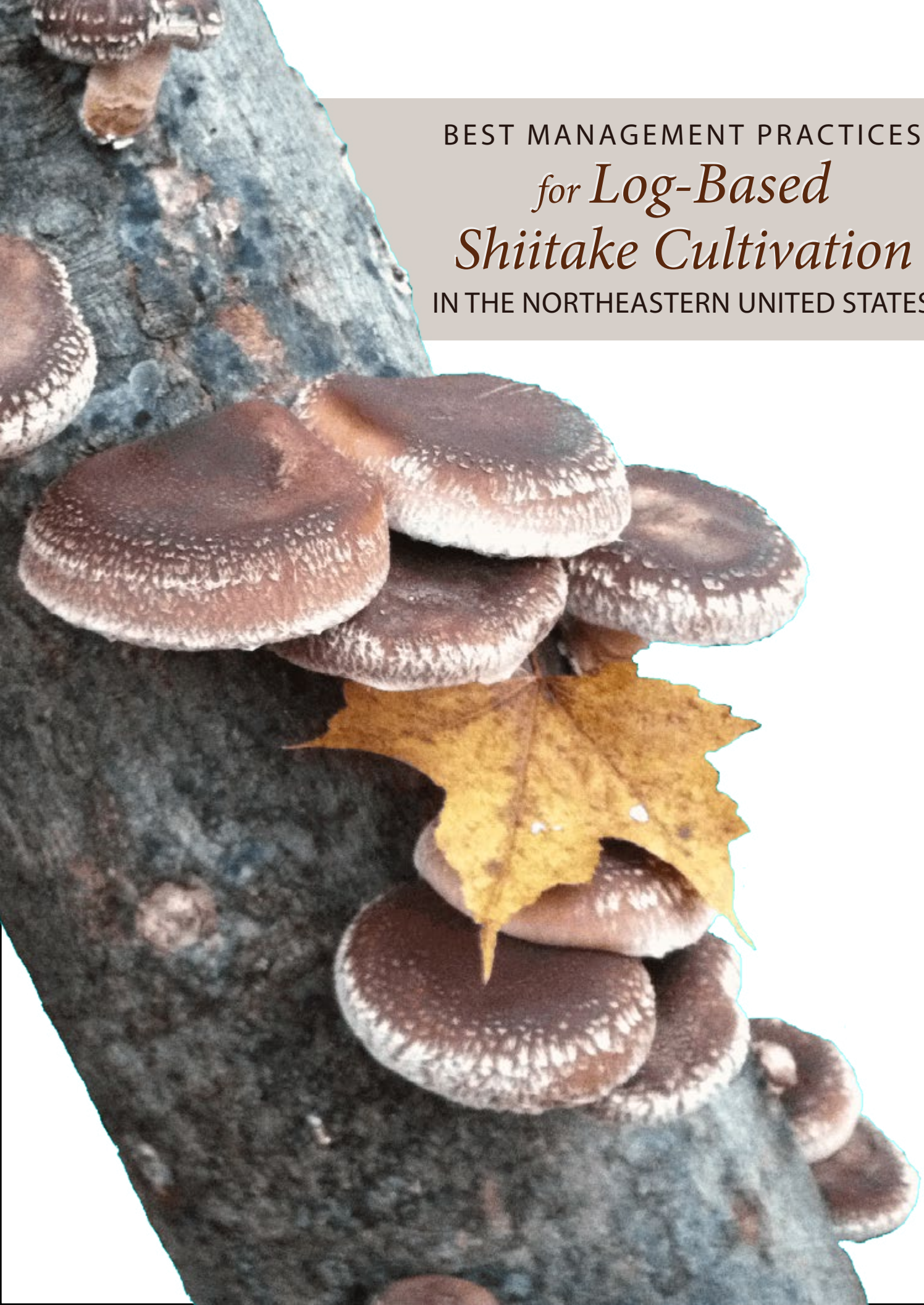
BEST MANAGEMENT PRACTICES

for Log-Based Shiitake Cultivation

IN THE NORTHEASTERN UNITED STATES



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NORTHEAST SARE
Sustainable Agriculture Research & Education

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Cornell University

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UNIVERSITY OF VERMONT EXTENSION
CULTIVATING HEALTHY COMMUNITIES

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Steven and Julie Rockcastle displaying their products (Ken Mudge, Cornell Univesity)

Series of photos taken of the shiitake operation at the Green Heron Growers in Panama, N.Y. (Steve and Julie Rockcastles, Green Heron Growers)

Table of Contents

Introduction.....5

Shiitake Mushroom Basics 7

Acquiring Logs & Bolts.....9

Inoculating Logs.....16

Spawn Run & Incubation.....23

Forcing Bolts.....30

Harvesting Shiitake.....39

Shiitake Storage & Preservation.....42

Marketing Forest-Grown Shiitake.....45

Enterprise Viability 48

First shiitake flush from a group of logs.
(Andrew Bojanowski, Eddy Farm)

This guide introduces the principles of shiitake cultivation. It combines insights gathered from professional growers, on-farm trial, and university-based research all within the northeastern United States. Keep in mind that the process presented herein may be slightly different amongst individual growers and will benefit from personal adjustments as the cultivator gains experience.

Introduction

To date, most forest cultivation of shiitake mushrooms has been conducted in the southern and Midwestern regions of the U.S. where the climate, available substrate tree species and markets differ from those in the Northeast. This manual outlines best management practices for shiitake mushroom cultivation and sales in the northeastern United States. In addition, the manual also includes anecdotes and tips from experienced growers in the region, data gathered from farms starting their operation, and the latest academic research.

Information Sources

Expert Tips and Tricks

Some of the growers involved in this project have been growing and selling shiitake mushrooms for many years. Wherever applicable, they have shared helpful tidbits that helped them save time and money, and increase their own mushroom production.

Expert Opinions

Shiitake mushrooms have been grown in the U.S. only since the early 1980s so the process of cultivating shiitake mushrooms is still in its relative infancy. For many topics, there is no definite "right" way. For these situations, we have drawn on expertise from growers through their hands-on experience. These included not only the original four expert commercial shiitake growers involved in the SARE project that culminates in this guide, but also may others participating in the listserv that was initiated to foster communication among many more growers. Use this information to help yourself make informed decisions.

Grower Results

Twenty-seven beginning growers were chosen to participate in a SARE grant "Cultivation of Shiitake Mushrooms as an Agroforesty Crop in New England." After attending a series of workshops including an on-farm visit to a shiitake grower and enterprise development training, each participant inoculated 100 bolts (logs) on their property with shiitake spawn, managed their laying yard, harvested and sold mushrooms, all the while keeping records of labor, expenses, production and sales. During the summer and fall of 2012 they completed their first harvest season and submitted their records. The results were analyzed to determine realistic estimates of the time requirements and costs of starting an operation and what profits they could expect to generate. Using their results, we were also able to draw some broad conclusions regarding production techniques.

EXPERT TIP: *Stay Connected*

Join the "Mushroom" Listserv:

To get connected to the Mushroom listserv:

- Send an e-mail to listserv@list.uvm.edu
- In the Subject line type: mushrooms
- In the body of the e-mail type: subscribe MUSHROOMS YOUR_EMAIL_ADDRESS
  For example: subscribe MUSHROOMS jane.doe@gmail.com

If you receive a confirmation message from LISTSERV asking you to verify your identity, just follow the instructions in the message.

Join the Northeast Forest Growers Network

On the website, you can post to the message board and check out other useful resources including the map of commercial mushroom growers, the latest research and informative videos. Go to the website located at *http://blogs.cornell.edu/mushrooms/.*

UVM Mushrooms Listserv

Since 2010, over 100 growers and mushroom enthusiasts have been involved in a Northeast-based mushroom listserv. Much of the material for this manual was drawn from valuable discussions that took place over the listserv. We encourage you to join the ongoing discussions by following directions on the left.

Northeast Forest Mushrooms Growers Network

The Northeast Forest Mushroom Growers Network website is the official online meeting place for the NE SARE-funded project, Cultivation of Shiitake Mushrooms as an Agroforestry Crop for New England. The aim is to provide information about the cultivation of specialty forest mushrooms and foster communication and cooperation among amateur and professional mushroom growers. On the website, you can learn about upcoming events and mushroom inoculation classes, download the latest fact sheets and publications, watch video demonstrations of inoculation techniques, register your farm in your mushroom grower directory and much more. **Check it out at *http://blogs.cornell.edu/mushrooms/*.**

Cornell University Ongoing Shiitake Research

Since 2006 Ken Mudge and coworkers at Cornell University have been conducting research on shiitake and other specialty forest mushrooms at the Arnot Forest near Ithaca, N.Y. This research has focused on four broad areas including substrate tree species, seasonal consideration, laying yard management, and cultivation of lion's mane mushrooms. The results of some of that research are shown in the graphs within this guide.

Shiitake Mushroom Basics

About Shiitake Mushrooms

The origins of shiitake cultivation have been traced back thousands of years to Japan. People often found these mushrooms growing on downed "shii" trees (this is where the mushroom got its name). People would take the mushroom-clad logs, place them next to logs without mushrooms and simply wait for the wind to disperse the spores. Thankfully, since then, a lot of research in Japan and China has gone into shiitake-growing techniques, and we don't have to wait for the wind anymore. In fact, shiitake is the second most produced mushroom in the world, following the common button mushroom.

Shiitake Mushrooms *(Lentinula edodes)* at a glance

Shiitake Form: Fleshy convex cap, slightly tough stalk

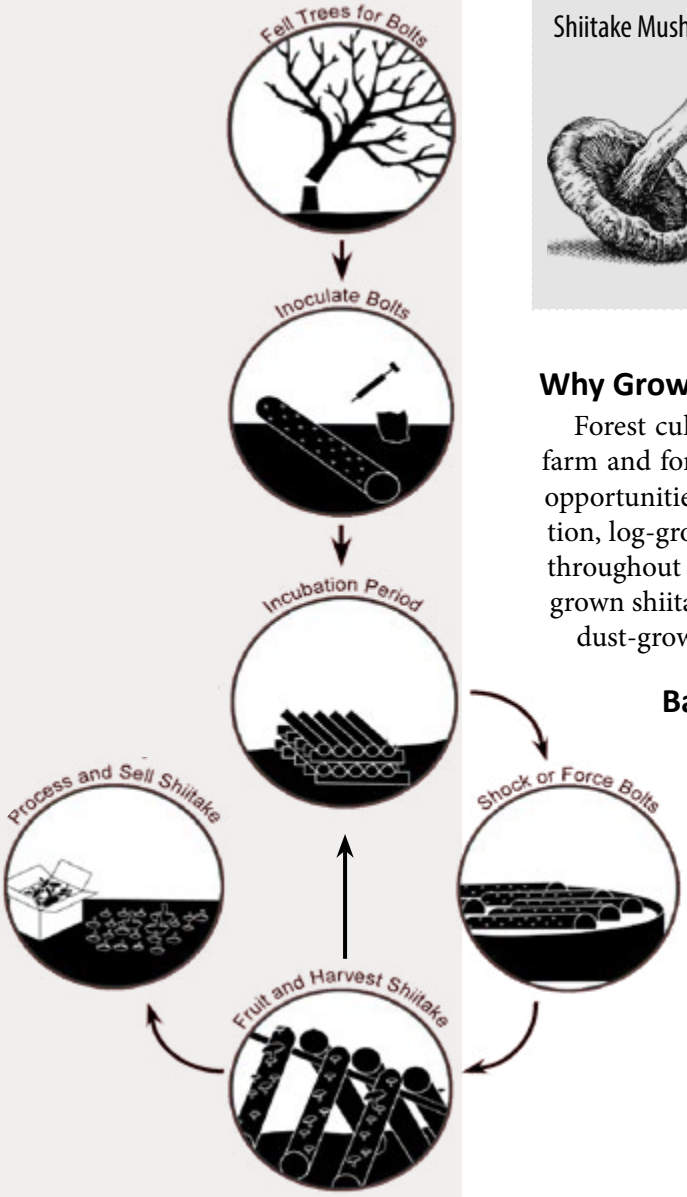
Color: light to dark brown cap, creamy white gills, light brown stem

Best grown on: hardwoods like oak, maple, ironwood

Spawn form available: plug, grain, sawdust, thimble

Average size at harvest: 3- to 6- inch diameter cap, 2- to 4- inch stalk

Flavor/aroma: Robust, earthy



Why Grow Shiitake

Forest cultivation of shiitake mushrooms can generate income, diversify farm and forestry enterprises, add value to forestry by-products and create opportunities for timber stand improvement. At the time of this publication, log-grown shiitake mushrooms were selling for $10 to $18 per pound throughout New England. Independent blind taste tests have found forest-grown shiitakes to be superior in flavor and freshness compared to the sawdust-grown shiitake mushrooms commonly found in supermarkets.

Basics of Shiitake Production

Production involves inoculating fresh cut hardwood logs by placing spawn (cultured fungus) into holes drilled in each log. Logs are then incubated in a "laying yard" under forest shade for about one year before fruiting (mushrooms) begins. The log will continue to fruit biannually for three to four years, generating upwards of 8 ounces of mushrooms at each flush.

Key Terms

- **Bolts:** A log inoculated with spawn.
- **Flush:** A group of mushrooms that fruited within a short period of time after a single forcing event.
- **Forcing:** The process used to trigger the mycelium to produce fruiting bodies (mushrooms) predictably, within a 7- to 14- day period.
- **Laying Yard:** The place where the logs are incubated and routine maintenance is performed. The logs usually remain in the laying yard for the rest of their productive lifetime, which includes both fruiting and harvest.
- **Mycelium:** The vegetative part of a fungus, consisting of a network of fine white filaments (hyphae).
- **Shocking:** Often used interchangeably with "forcing." Means of triggering shiitake mushroom production (forcing) which involves soaking logs in cold water for an extended period of time (12 to 24 hours) to induce fruiting.
- **Spawn:** Vegetative mycelium (fungal strands, NOT spores), cultured on sawdust and a little grain under sterile conditions, and used to inoculate logs.
- **Spawn Run:** An incubation period bolts undergo after inoculation during which the shiitake mycelium colonizes the wood.

Acquiring Logs & Bolts

Choice of Log Species

Tree choice is very important; the species of tree used will affect the amount of mushrooms produced each flush, the amount of flushes you can expect from a single log, and even the taste and size of the mushrooms produced. See sidebar entitled, "Tree Species and Taste" for more information regarding how the tree species influences mushroom taste.

RESEARCH: ***How does log species influence mushroom taste?***

Patrons at the Trumansburg Farmers Market, in Trumansburg, NY were not able to taste the difference between shiitake mushrooms grown on different tree species. This does not mean that there are not differences in the flavor of shiitakes grown on different tree species; it simply means that the differences, if there were any, were too subtle to be detected by the average consumer.

Culinary professionals, however, were able to generate a list of descriptive adjectives that differentiate the subtleties of flavor between shiitakes grown on different tree species. Mushrooms grown on Sugar Maple were described as having umami, smooth, mild, and clean flavors, mushrooms grown on Red Oak were described as having meaty, heavy, and hearty, while mushrooms grown on Carpinus were described as having flavors described as caramel, banana, and buckwheat pancakes.

(Adapted from thesis research by B. Sobel (2013) of Cornell University)

EXPERT TIPS: ***Species Identification***

"Tree species identification is a worthwhile skill to hone as tree species are often easy to mix up. If you are unsure about what species you have, I recommend getting some verification ... there are often forestry homeowner associations in all areas that can help."

-Steve Sierigk, Hawk Meadow Farm

EXPERT OPINION: ***Tree Species and Taste***

"Concerning the quality of shiitakes grown on different log substrates ... the longer I do this the more I notice differences on shiitakes grown on different woods, from taste, shape, how they pick.

One restaurant loves the spicy flavor that they detect in the bitternut hickory shiitakes so I often send these their way. Shiitakes grown on Carpinus (Musclewood) were the hands down least favorite in our group of 16 tasters with adjectives like "insipid" and "flavorless" coming up when compared to others.

Keep in mind that they all taste like shiitakes and are all perfectly acceptable and marketable. It is just fun to note and be aware of the differences ... as our sense of taste is highly personal."

-Steve Sierigk, Hawk Meadow Farm

Mushroom farmers have grown shiitake on many tree species in the Northeast, with varying degrees of success, and varying from one grower to the next. Oak has developed a reputation as the gold standard, but many growers have found that other species like sugar maple, beech and musclewood work as well as or better than oak. Conversely, red maple, poplar, black locust, fruit wood and ash are widely known to be less suitable.

In most cases, growers opt to use whatever hardwood species are available. In other situations, one may choose species with low timber value but which are good shiitake substrates like beech and musclewood; removing these trees can improve timber stand quality while producing a bumper crop of mushrooms.

Because different tree species respond differently to the set of conditions under which they are being cultivated, it is difficult to rank species from best to worst. Variables like the time of year, laying yard conditions, spawn strain, properties of the tree before it was cut down, and climate can all effect how well a certain species of log performs. Based on the input from research and professionals we've divided common northeast species into four tiers from excellent to poor. Species in a single tier generally have a similar performance

EXPERT TIPS: *Acquiring Logs from Unique Sources*

"Developing a connection with road clearing crews, local arborists, and tree companies can be an essential component of reducing the initial costs for a shiitake operation. A thorough description for the types and quality of logs must be made, and sometimes even inviting these people to your operation can be helpful so that a clear understanding for the quality and size of log is developed. Safety is essential when/ if an arborist or state team is approached and a phone call asking for permission to access or work with their crew (when picking up logs) is typically mandatory.

"State Forestry personnel sometimes allow state residents to apply for firewood permits, which for the state, the end purpose (firewood) of the logs is not necessarily the agenda, but rather thinning the logs from the forest is. A mushroom grower can use this opportunity to harvest trees at a reduced rate, or extend the life of their own forest if acreage is minimal."

- Nicholas Laskovski, Dana Forest Farm

"Because oak is a valuable timber species, forest owners who include timber production as part of their woodland management goals may be reluctant to cut large amounts of young oak for shiitake cultivation. However, tops left after logging are often of an appropriate size to be used as bolts (logs) although timing of when the logs were cut might be less than optimal for mushroom production.

"Since I prefer oak I have put the word out to tree workers in our area that if they are ever taking down oak in our area let me know. This has been a great option as these folks better understand what I am after as what I have gotten from loggers has been less carefully handled. I encourage any of you who may want to source oak if you don't have any in your woods to cultivate such relationships."

-Steve Sierigk, Hawk Meadow Farm

(Steve and Julie Rockcastle, Green Heron Growers)

but will outperform species in the preceding tier, but there are exceptions where a species in a lower tier may perform better than one in an upper tier. For example oak often out performs beech, but in our research site at the Arnot Forest, beech frequently out performs oak.

EXPERT TIPS: *Musclewood or Ironwood*

Musclewood (*Carpinus*) has rippled/ muscle-like smooth bark. The bark of Ironwood (*Ostrya*), by comparison, is flaky.

Tier 1: Excellent Species

- **Oak (*Quercus*):** Research at the Cornell University has shown that red and white oak exhibit similar performance as substrates for shiitake. Anecdotally, some growers claim that red oak is colonized more rapidly, less subject to competing fungus compared to white oak. Oak tends to be productive for more years than some other species, which means that you typically get more mushrooms for the initial amount of work. Shiitake mushrooms grown on oak tend to fruit within a short (weeklong) time-frame facilitating an easier harvest.
- **Sugar maple *(Acer saccharum)*:** Sugar maple is a reliable substrate, and a good choice for the Northeast where thinning of a sugarbush is a common practice to improve stands for maple syrup production. Lesser value trees can be thinned out and used for high-value Shiitake production. It is an excellent producer, the shiitakes taste wonderful, and are compatible with cold weather shiitake strains.

Tier 2. Very Good

- **American Hophornbeam / Ironwood (*Ostrya virginiana*):** This species is highly productive; some growers have found it produces equally well if not better than oak.
- **American Hornbeam / Musclewood (*Carpinus caroliniana*):** This species produces large impressive specimens, although some growers have found that shiitakes grown on musclewood have less desirable (although still adequate) flavor.

EXPERT OPINION: *Beech Bark Disease*

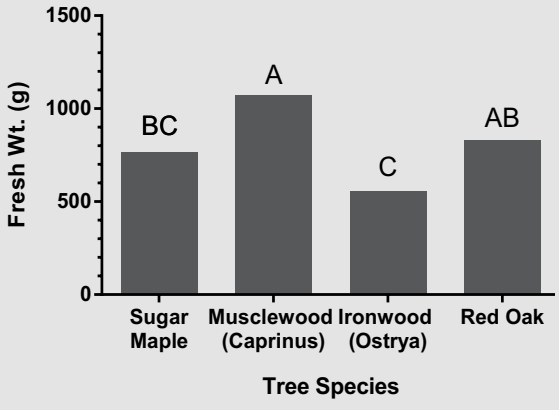
"Beech Bark disease is a saprophytic fungus that attacks the vascular tissue of the tree and weakens the bark. The Nectria fungus won't pose a direct competitive threat to shiitake mushroom mycelium. The issue is, once a bolt is inoculated, the wounds in the bark (caused by an outer tissue deficiency) will increase susceptibility to additional epiphytic fungal competition, increase moisture loss, and cause a reduction of available surface area for shiitake mycelia where sapwood has decayed. Mushroom growers who want to salvage beech can do so by using logs where Beech bark disease has not yet become serious."

- Allan Thompson, Consulting Forester

- **American Beech *(Fagus grandifolia)*:** Most people find that American beech is less productive than oak but will still produce an adequate harvest. However during research trials at Cornell, beech has consistently outperformed oak. Many landowners may have a surplus of beech as a consequence of beech bark disease infestation. See sidebar addressing beech bark disease for more information. Keep in mind that if you cut

RESEARCH: *How does log species effect shiitake production?*

Researchers at Cornell University measured the effect of tree species effect on shiitake mushroom production over 4 years. They achieved the greatest yields on Musclewood (Carpinus) and Red Oak. Means with different letters are significantly different ($p<0.05$)



EXPERT OPINION: *Species Choice*

"I would encourage growers to try a mix of these woods to see firsthand what the performance is in their yard ... we may all be surprised. For instance a grower I consulted with near Bainbridge N.Y. sent me some photos of her yard in its first flush. She had used red maples. I primed her to be disappointed and she was ready to be under-whelmed. However the photos she sent me showed logs nicely covered with shiitakes and when I took great care of my red maple logs mine never produced close to what she had ... so what gives? "

-Steve Sierigk, Hawk Meadow Farm

thin barked species like beech and red maple too late in the spring when the buds are breaking dormancy, the bark will separate from the wood and slide off very easily! This can be avoided but cutting in winter or early in the spring before bud swell.

Tier 3. Good

- **Sweet Birch / Black Birch / Yellow Birch (*Betula lenta* and *Bentula lutea*):** Both colonize well and make nice shiitakes.
- **Bitternut Hickory *(Carya)*:** Hickory seems slower to colonize than other species but once it gets going it makes some very high quality shiitakes. Growers have reported that the yield is close to at least fifty percent of red oak. They also grow fairly straight, which is a bonus when handling or inoculating logs.
- **Red Maple:** Red maple is not regarded highly among commercial growers however it might be appropriate for hobby grower. Red maple has thin bark and tends to wear out sooner than the others species. Experienced growers claim that, from red oak logs, they expect 8 serviceable flushes; comparatively, when fruiting from red maple, growers expect only 4 or 5 flushes with smaller yields per flush. If you chose to use red maple, note that it is a softer wood, and tends to dry out sooner than others. Consequently, more maintenance soaks may be necessary, relative to other species. Also, be aware that if you cut red maple too late in the spring, the bark will separate from the wood and slide off very easily! In addition, a warm weather shiitake strain is recommended. Despite these quirks, it can still be used as a fruiting medium, and it can be a good producer, especially in its first year as long as moisture loss is prevented, by shading and other cultural practices discussed below.

Tier 4: Not Suitable

- **White Ash:** White ash is generally sluggish and not very productive.
- **Elm:** Not very productive.
- **Soft Hardwoods:** We do not recommend using aspen or other soft hardwoods. These species might be appropriate for other types of mushroom production, such as oysters.
- **Evergreen Species:** Do not use wood from any coniferous evergreen tree (pine, spruce, hemlock, etc.).
- **Fruit Wood:** Apple, cherry and other fruit tree are not recommend.

Other Species

Further research is needed with chestnut, walnut, alder, elm, tupelo, and other hardwood species.

EXPERT TIPS: *Sapwood:Heartwood Ratio*

"I can have 2 similar 4-inch bolts of red oak ... one that was open grown and has a great sapwood layer ... vs. a slow-growing forest grown red oak that was struggling for growth rings with minimal sapwood. Both are 4-inch diameter bolts but I have found that I will expect perhaps to 4- to 6- times more shiitakes on the fast growing, fat sapwood layer bolts (through the eyeball data collection method ... no hard data mind you)."

-Steve Sierigk, Hawk Meadow Farm

Tree Section within a Forest

Only living healthy trees should be cut down. You cannot grow shiitake on dead wood, such as old logs in your yard or woodland, or firewood because existing local fungi have contaminated these logs and/or the logs have dried out.

EXPERT TIPS & TRICKS: *Safe Logging*

The "Game of Logging" (GOL) is widely acknowledged as the premier chainsaw training program in the country, offering hands on training in a competitive environment. Top instructors across the country combine demonstration with participation to teach safety, productivity, conservation and cutting techniques. To sign up for a course, go to *http:// www.gameoflogging.com*.

The ratio of sapwood to heartwood within a log strongly impacts shiitake production. Shiitake mycelium colonize the sapwood section (the lighter colored outer layer) of a log. You can maximize the area available for mycelium colonization by selecting vigorously growing trees with a fat ring of sapwood. See sidebar entitled, "Sapwood : Heartwood Ratio" for more information.

"Site index" is a forester's means of estimating how suitable a particular site is for a given tree species. It depends on measurement of both tree age (increment borer) and tree height (clinometer) on your site. Site index tables have been published for many species of trees. So if your site has a high site index for red oak, it is more likely to have vigorously growing (fat sapwood) trees and will be a greater mushroom producer in the long run. Low site index trees are likely to be the slow growing oak that will likely be a dog for mushrooms.

EXPERT OPINION: *Winter Harvesting*

"Late winter or very early spring inoculation can be successful. It is a smart time management technique, where the work gets done while the overall farm workload is less, before primary growing season farm tasks ensue. Some growers in the Northeast report the potential to have a late summer flush on logs inoculated very early that same year if conditions are right. The disadvantage of very early season inoculation is it can be unpleasant to work in cold, wet conditions. Working with Shiitake spawn in freezing conditions will not kill it off, but frozen spawn is difficult to handle."

- Nick Laskovski, Dana Forest Farm

"Winter cut is best for many reasons ... but as a grower sometimes you just get logs when you get them. The shiitake season has its time for different operations ... it is just generally easier to deal with log acquisition in winter whether it is on your own land or sourced out. It is more straightforward to work in the woods when the foliage is off and perhaps a little snow is on the ground. Not much else is happening in the shiitake world that time of year."

-Steve Sierigk, Hawk Meadow Farm

Felling Trees

Mushroom growers who are forest owners (or have a working relationship with forest owners) should establish a management plan for their woodlot and have training in the safe use of a chain saw. See sidebar entitled, "Safe Logging" for more information.

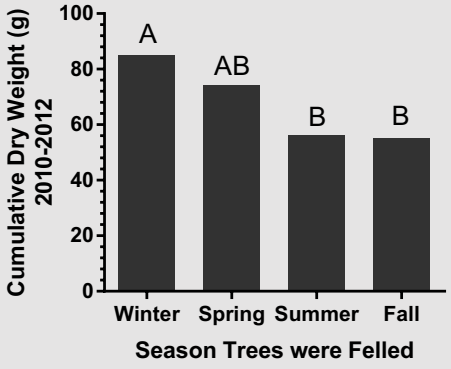
Time of Year

Early spring, before the trees leaf out, is the season most often suggested for felling trees and inoculating bolts for mushroom production.

You may also cut trees during the winter months and store the logs for several months before inoculation in the spring. Farmers who tend to be very busy in the spring season may find this schedule more advantageous. If you are harvesting logs in the winter when the ground is still frozen, pile them up

RESEARCH: *How does the season during which the tree was felled effect shiitake production*

Researchers at Cornell University showed that winter and spring are the ideal time period to cut and inoculate logs. Yields from logs harvested during this time were significantly greater than logs harvested in the summer and fall. Means with different letters are significantly different ($p<0.05$)



between some trees trying to keep them out of direct sun and wind in order to ensure they maintain high moisture levels. If it is practical, stack the logs off the ground to avoid them from becoming muddy during the spring thaw. Logs can be covered with clean snow to block out drying winter sun and wind. The melting snow keeps logs hydrated in spring before inoculation. For more information about winter harvest, see sidebar.

Inoculate the logs as early as possible to reduce contamination by other competitive fungi, and avoid logs drying out past the point where spawn will establish in the log. See research box on page 16 for more information.

Importance of Intact Bark

For a healthy mushroom log, the bark should be intact. Damaged bark allows for greater chance for invasion by 'weed' fungi species and increased moisture loss. Although the bark may become damaged over time, care should be taken to keep it on the bolts as long as possible. Sometimes damage to bark during the felling or skidding process is unavoidable. A good technique is to wax over damaged spots during inoculation to seal in moisture and block out competitive fungi.

Cutting time affects the likelihood of the bark falling off, or slipping. In the winter months of full dormancy, before bud swell, bark is tighter because the vascular cambium is dormant, and therefore cutting during these months may help in preserving bark integrity. Conversely, cutting in the late spring and summer months may lead to a greater incidence of bark slippage.

Ideal Bolt Size

Logs should typically be 4 to 6 inches in diameter, although when felling trees, there will often be larger logs available. Larger logs can be used but they are obviously more difficult to manage. The 4 to 6 inch diameter range is ideal because it optimizes the amount of sapwood per volume of log. The sapwood is the primary part of the log that the fungi will colonize. More research is needed to determine the rate and degree to which shiitake mycelium colonize heartwood. The sapwood to heartwood ratio is higher and preferable for cultivating shiitake in a tree that has been growing vigorously under optimal conditions compared to a less vigorous tree.

Length is not as important as diameter for health of the fungi, but a 3- to 4- foot-long is manageable for transport and individuals to carry. A common technique is to cut different lengths based on the diameter. Smaller diameters can be closer to 4-foot in length, while larger diameters up to 8 inches can be cut shorter so they can still be carried.

Heavier logs can also be inoculated using a cold weather strain that doesn't necessitate shocking; these logs can remain in an A-frame stack for their useful life and won't need frequent handling. (See section on Cold Weather strains, page 18 and 19)

EXPERT TIP: *Logs Size Effects*

"It has been shown over time that this size log will generally colonize at a specific rate which will allow for the fruiting of shiitake to happen in the following year. Larger logs may take longer to colonize with shiitake mycelium and may not be ready for production until 18 to 24 months."

- Nick Laskovski, Dana Forest Farm

EXPERT TIP: *Log Costs*

"If you are doing all the labor 50 cents to $1 per bolt seems reasonable to me, although I always offer to thin woods for people and they benefit from the increased forest health/productivity (if a thinning is done well) - I take logs as my "pay" which is a fair trade. Also have offered to leave/split stems over 10 inches for landowner firewood as trade."

-Steve Gabriel,
Wellspring Forest Farm,
Mecklenburg NY

Buying Bolts

You may also consider buying pre-cut lengths (at the time of this writing, loggers in the northeast were selling bolts to Shiitake growers for $1 to $2 per bolt). This is in line with what loggers would normally get for firewood. Buyers should try to purchase logs in good condition with the bark intact, and few places of rot or scarring. Be sure to ask when logs were cut and what the storage conditions prior to delivery or pick-up were. Remember that if the logs were stored in the sun, the moisture content is likely to be too low.

If you are doing all the labor, 50 cents per bolt is more reasonable. You can also offer to help the forest owner with thinning trees from an overcrowded stand, generally known as Timber Stand Improvement. They will benefit from the increased forest health/productivity (if a thinning is done well), and you can take the logs as "pay" - a pretty fair trade. Be sure to confirm that cutting trees fits in with the landowner's forest management plan.

Acquiring bolts from local arborists may be an option for you, too. Be sure to inform yourself about local or regional restrictions on transporting "fire wood" (as shiitake bolts are considered, even if they are fresh cut) from one location to another, as a pest control measure. In most areas, it is illegal to transport firewood across state lines and transport from one area to another is highly discouraged. For more information about unique sources of low-cost bolts, "Acquiring Logs from Unique Sources" on page 10.

It's important to ensure that whoever you buy wood from is managing the woodlots in a sustainable way. If they are not working with a forester, or have no background in forest ecology or management for health, it is advised to avoid purchasing logs from these individuals.

What will it take to create 100 bolts?

12	$45	Chainsaw Chainsaw Oil Gasoline Tarps
Hours of Labor	Worth of Supplies	

*Values based on data collected from 17 farmers starting a shiitake operation

Inoculating Logs

In log-based cultivation, the spawn consists of a mixture of vegetative mycelium (fungal strands called *hypheae*, NOT spores), sawdust and a little grain to form a substrate (nutrient source). The shiitake mycelium feed on newly dead hardwood; they can be introduced to the log through either the dowel or sawdust inoculation methods.

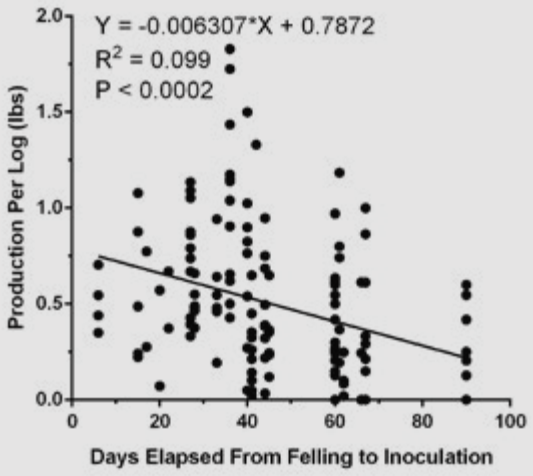
When to Inoculate

Bolts should be inoculated anytime between one day and three weeks after the tree is felled - sooner is better (see the figure below). Research at Cornell's Arnot Forest has shown that winter and spring inoculations are ideal; however, summer and fall inoculations also produce sizable harvests.

Logs can be inoculated immediately after they are felled; there is no need to "cure" the log for a few weeks. Do not wait longer than three weeks to inoculate; the longer you wait, the more likely the log is to be infested with competitive fungi and/or dry out. The one exception is trees felled during winter; these may be stored for longer period of time in preparation of an early spring inoculation. When storing logs for any length of time, be sure not to store bolts in the sun in order to minimize log drying. Clean snow can be used, wherever possible, to keep logs covered.

RESEARCH: *Timing Log Inoculation*

Try to inoculate your logs as soon as possible after felling the trees. Research shows that the less days that elapse from felling until bolt inoculation, the greater the production per log.



Workshop participants at Red Manse Farm, (Loudon, N.H.) inoculating logs using sawdust spawn and inoculators.
(Allen Matthews, Chatham University)

EXPERT TIPS & TRICKS: *Soliciting Volunteer Help*

Many of the required tasks, particularly bolt inoculation, can be quite tedious. Many growers choose to solicit help from volunteers and friends in order to get the job done. Some organizations or privately sponsored entities charge a small fee for an inoculation event (workshop). The following are some tips to help to achieve a high volunteer turnout:

- Advertise the event as an informal class in shiitake mushroom production. Teach your volunteers enough to begin their own small operation.
- Turn the day into a party. Play music, provide refreshments, and be merry.
- Offer a free meal.
- Offer a shiitake taste-testing.
- In appreciation for their help, send each participant home with a shiitake log that they have inoculated themselves. They should be able to fruit the log in their backyard.

EXPERT OPINION: *Inoculation Methods*

"Sawdust spawn allows the inoculator to work faster than with a dowel and hammer. Also, I believe that sawdust spawn leaves less room for contamination because the spawn is not touched by your hands."

- Nick Laskovski, Dana Forest Farm

Bag of Sawdust Spawn and Inoculator.
(Allen Matthews, Chatham University)

Plug Spawn being placed in hole.
(Jim Ochterski, Cornell University)

Selecting Appropriate Spawn

Spawn Type

Bolts can be inoculated with sawdust spawn, plug spawn, or thumb spawn. There are advantages and disadvantages to each. Plug spawn is very simple to use—the only tool needed is a drill and hammer or mallet. The drawbacks are that plug spawn is slightly more expensive per log than sawdust spawn, the mycelium may take a while to migrate into the sapwood of the log, and the inoculation operation is significantly slower than the sawdust spawn method. Sawdust spawn is slightly cheaper than plug spawn, but it requires a special tool (inoculator), either purchased or homemade, to insert the sawdust into the hole. In addition to its lower cost, the mycelium contained in sawdust spawn moves out into the log more quickly, giving somewhat faster production. This guide specifically describes the sawdust spawn method, which is more common for commercial enterprises.

EXPERT OPINION: *Strain Choice*

"Most growers in cooler climates tend to use Wide Range strains in the majority of their logs. I recommend that people always start here and then branch out into the WW and CW strains."

- Steve Gabriel, Wellspring Forest Farm, Mecklenburg NY

Choosing Spawn Strain

Mushroom supply catalogs describe strain categories that differ in the temperature range at which they fruit. Each category described below includes several strains (varieties) of spawn and each of these is a genetically unique clone. The differences between each strain temperature category are also summarized below. Generally speaking, we recommend trying a variety of different strains to see what works best under your specific conditions. By using a combination of strains, many growers are able to maximize the length of their fruiting season.

People sometimes wonder if there is a taste difference between different strains. Although there isn't data on the subject, commercial growers tend to find that cold weather strains produce shiitake with a more intense flavor. Try a few strains and see what you think. If you intend to try only one strain the first time around, we recommend a WR strain.

- **Wide Range (WR) Strains:** These are the favorite among both commercial growers and beginners. They are reliable. Fast spawn run and fruiting allow a faster return on investment. WR strains can be force fruited easily and recover vigor more rapidly after fruiting.
- **Warm Weather (WW) Strains:** Warm Weather strains produce the highest

EXPERT TIPS: *Cold Weather Strains*

"I've been using the cold weather strain Snowcap for several years (from Field and Forest), and have been harvesting them for more than two weeks (they started pinning in early April) - with no cover. They sailed right through the last cold snap (low-20s, daytime temps not much above freezing) and are coming on strong now.

"I am shocking 20 logs per week of those that didn't 'wake up' naturally, and they are also pinning happily now.

"For people in the North Country like me (20 miles from Canada/we get below-40-degree nights right into June, and again by late August), you might consider diversifying your strains.

"I highly recommend SNOW CAP, and also BOLSHOI BREEZE. Both can keep fruiting right into November - and tend to pick up when the WR and Warm-weather strains poop out."

-Robert Wagner,
North Woods Shiitake

quality mushrooms during the hot summer months and early fall. They respond well to soaking for commercial production, and tolerate warmer soak water than other strains. They are also often recommended for growing Shiitakes on some of the softer hardwoods, such as red maple.

- **Cold-Weather (CW) Strains:** These tend to fruit in early spring and late fall. These strains require a longer spawn run than other stains. They won't reliably fruit after being forced, so most people let the natural rise and fall of wintry temperatures initiate fruiting. See side-bar for more information about cold weather strains.

Using Cold Weather Strains to Extend Season

Cold weather strains are well suited to the Northeast where the growing season is short and the time frame for fruiting wide range and warm weather Shiitake strains can be limited. Since cold weather strains fruit during the transition times from spring to summer and summer to fall, they can be used as a strategy for season extension. Even though cold weather strains do not respond well to shocking, Northeast-based growers with enough cold weather strain logs can supply late spring and fall markets when other mushroom growers can't. Learn more about season extension using cold temperature strains on page 31.

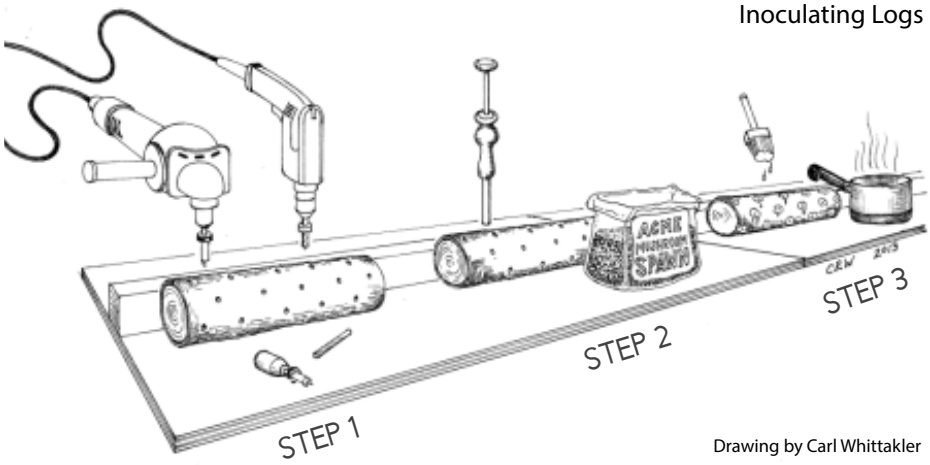
Inoculation Procedure Using Sawdust Spawn

Log inoculation is a three step process. First a series of small holes are drilled into each log. Each hole is then tightly packed with spawn. Lastly, the surface of each hole is covered with wax to ensure optimal mycelium growing conditions and reduce contamination by other fungi species. Each step is described in detail on pages 20 through 22.

This process can be quite repetitive and time consuming; however, many growers have found innovative ways to speed it up. For example, you can solicit volunteer help by hosting an inoculation party or informal mushroom inoculation class; see page 17 for more details. You may also want to consider setting up a small assembly line. Building an inoculation table is a great way to save time and your back. Ideally, you will want a table that keeps the log from rolling over when you are working with it, but also makes it easy to move the log from one station to another. Some handmade inoculation tables are pictured below to offer inspiration.

Homemade inoculation table.
(Ross Conrad, Dancing Bee Gardens)

Homemade inoculation table at Red Manse Farm, N.H.
(Allen Matthews, Chatham University)



Drawing by Carl Whittakler

Step 1: Drill Holes in Bolt

You will need to drill a series of holes in each log, 7/16" diameter and 1.25" deep. This dimension matches the inoculator tool used to plug the holes with spawn. Start 1 inch from the end of the log, drill holes 3 inches apart in rows along the length of the log, with 3 to 4 inches between rows. A general rule of thumb is to estimate the diameter of the log, and have as many rows of drill holes as there are inches of diameter; for example a log with a 6 inch diameter needs 6 rows. Plan for a minimum of 30 to 40 drill holes per log, depending on log diameter. The holes should be staggered in a diamond pattern to ensure rapid growth of the fungus throughout the log.

Drilling holes in bolts using Angle Grinder
(Earl Tuson, Red Manse Farm)

Closer spacing increases the rate of colonization and results in more rapid mushroom production; however, spawn costs are also greater. It is very common on bolts to have small areas of bare bark where bark was damaged or branches were cut off. Drill holes in these areas as well. Once inoculated and waxed over, the damaged or bare areas will be sealed, increasing chances for a thorough and successful spawn run.

EXPERT TIP: *Drilling Safety*

"If you are using an angle grinder to drill holes (highly recommend) for sawdust inoculation, purchase a bit specifically manufactured for high-speed drilling. Do not use a regular drill bit for a high-speed (10,000 rpm) angle grinder as these may shatter".

- Ken Mudge, Cornell University

High speed drill bit for angle grinder.
(Ken Mudge, Cornell Univesity)

EQUIPMENT AND TOOLS: REQUIREMENTS AND RECOMMENDATIONS

Although you can use an electric hand drill, if you are drilling more than 50 to 100 logs, we highly recommend using a mini angle grinder outfitted with an adaptor and high-speed drill bit. While equipping an angle grinder with a drill bit is expensive, it is possible to move very quickly with this tool, reducing the time spent per log. This is especially useful for larger operations.

Power Drill Method
(Not recommended for commercial enterprises)

- Power drill (~2500 rpm) ($30-$150)
- Drill bit - 7/16" with depth stop ($12 - $15)

Angle Grinder Method

- Mini angle grinder (10,000 rpm) ($75-$170)
- Angle grinder adaptor ($35-$40)
- Angle grinder drill bit - 7/16" with depth stop ($13-$20)

EXPERT TIP: *How much spawn to buy*

Most growers estimate that one 5 pound bag of spawn will inoculate 20 to 25 logs (4-6" wide X 36" long).

Step 2: Inoculate the Bolts

Spawn Inoculators
(Steve & Julie Rockcastle)

To inoculate the logs with spawn, you will need a tool specifically designed to inject sawdust spawn into the hole, known as an inoculator. After the holes are drilled, place the spawn into the holes, bringing the shiitake mycelium in contact with its new food source (substrate), the log. When using sawdust spawn, take care to avoid handling the spawn as much as possible in order to avoid contaminating the spawn. Stab the inoculation tool into the spawn a couple of times, filling the chamber with sawdust. Then place the inoculator over the hole in the log and eject the spawn into the hole. The spawn should be tightly packed into the hole and rest approximately 1/8 inch below the surface of the log. Packing the spawn in below the surface enables a minimal amount of wax to be used, and allows the wax to adhere effectively to the surface of the plug hole.

EQUIPMENT AND TOOLS: REQUIREMENTS AND RECOMMENDATIONS

Inoculating tools come in two styles: The thumb style is designed to be operated with one hand, leaving the other hand free to hold and turn logs. The palm style requires both hands. When we asked local experts which type they preferred, everyone unanimously preferred the palm style inoculators which is "less stressful from a repetitive motion perspective."

Inoculation Tool: $27 to $30 each

EXPERT TIP: *Wax Safety*

"It is worth noting that heated wax has a very low flash point and can be highly flammable in very dry conditions or where there are sparks. Wax needs to be heated hot so it melts and stays melted while applying, but care should be taken not to heat it excessively. Wax should be melted nowhere near where small children play. The wax pot and heat source should be on a solid surface that is independent from the drilling station which rocks and rolls. Melted wax should be monitored at all times and should never be left unattended. Refrain from smoking, operating power tools, welding torches or having any other source of spark near melting or melted wax."

-Ben Waterman, UVM Extension

Step 3: Waxing the Bolt

Waxing over spawn holes using daubers
(Steve & Julie Rockcastle, Green Heron Growers)

Waxing the holes helps seal in moisture so that the spawn does not dry out and reduces contamination by competing fungi species. Completely seal each hole using food grade wax. The wax should be very hot (lightly smoking) when applied in order to ensure an airtight, flexible seal. If the wax turns white immediately after it is applied to the log, it is not hot enough. To apply the wax, use a wax applicator to transfer the hot wax onto each hole in the log. Care should be taken to seal the hole. One dip of the applicator should complete a few holes.

Some growers choose to wax the ends of each mushroom log either by dipping the log directly into the pot of melted wax or by painting each end with a paint brush soaked in wax. Other growers skip this step. Some growers wax ends to cover over cracking in the wood only when they see logs starting to dry out. Logs with waxed ends may be slower to absorb water during maintenance or fruiting soaks and thus may require more time to achieve the desired effect. An experiment at Cornell's Arnot Forest found no difference in mushroom production between end-waxed and non-waxed log ends.

The importance of this step may vary based on climate, which largely governs how crucial it is to strictly manage moisture levels. Waxing the ends will keep moisture in and prevent competitive fungi from gaining a foothold. However, wax is also one of the main production costs and the waxing process adds considerable time to the inoculation process. A cost-benefit analysis of additional wax cost and shiitake yield has not yet been conducted.

EXPERT TIP: *Wax Cracking*

If logs are inoculated in the spring, the mycelium will likely fully colonize the logs by winter. Cracking of wax after logs are fully colonized, most likely won't effect mushroom yield.

EXPERT TIP: *Wax Ingredients*

"Cheesewax and paraffin contain petroleum. This should not be construed that the mushrooms will also contain petroleum - I tell people that's it's the equivalent of growing an organic tomato in a plastic pot.

"Some cheese waxes are approved for organic production. Buy from suppliers, such as Field & Forest Products, who produce certified organic spawn and have had their wax approved for use in organic mushroom production."

- Steve and Julie Rockcastle, Green Heron Farm

EQUIPMENT AND TOOLS: REQUIREMENTS AND RECOMMENDATIONS

Cheese Wax ($2-$4 / pound)
Although you can you use any food-grade wax (cheese wax, beeswax, or paraffin wax), each has its advantages and disadvantages. The disadvantage of beeswax is it tends to crack at very low winter temperatures, but the advantage is it is often readily available at low cost. If you use paraffin wax be aware that it may not be acceptable for organic mushroom production.

Stove to Melt Wax
Electric skillets work particularly well to melt the wax, however you have to put a pot on the electric skillet to hold the wax. A skillet alone is too shallow and dangerous. They are sturdy, portable, and the temperature control is easy. You can also heat the wax in a pot over a portable propane or white gas stove. Wax should be heated to 350-400 degrees F (wisps of smoke should be present).

Wax Applicators ($0.15-$1.00)
You can apply the wax in a number of different ways. Foam paint brushes (1") are very effective. Cotton daubers are cheaper than foam paint brushes. These small cotton balls on the end of a wire handle are available from select mushroom product suppliers.

What will it take to inoculate 100 logs?

30 Hours of Labor

$160 Worth of Supplies

Inoculation Tools
Wax
Drill Bit
Angle Grinder Adaptor
Wax Applicators
Spawn
Angle Grinders
Stove

Spawn Run & Incubation

EXPERT TIPS: *Monitor Your Mycelium*

During the incubation period, you can monitor the growth of the mycelium by looking at the ends of the logs. Shiitake mycelium will appear white and often slightly fluffy at the end of the log.

Creating a Laying Yard

Before you begin, think about where you are going to keep all the logs once they are inoculated with mushroom spawn. This will become the laying yard: the place where the logs are incubated and routine maintenance is performed. The logs usually remain in the laying yard for the rest of their productive lifetime, which includes both fruiting and harvest.

Year-round shade (75 to 100 Percent) and High Humidity

Almost nothing is more important than laying (incubating) the logs under year-round shade in order to keep the logs from drying out due to sun and wind. A laying yard beneath the canopy of a coniferous forest is best. Hemlock provides especially dense shade. A deciduous canopy will suffice but it will be necessary to protect the logs with 80% shade cloth or pine boughs during the winter. For smaller operations in select circumstances, behind the north side of houses, sheds or other structures can provide effective, year-round shade.

Access and Relative Location

Ideally the laying yard should be accessible by a vehicle or tractor and close to your home/farm. You should also consider its proximity to electricity (necessary to inoculate the logs) and water (necessary to irrigate and soak the logs). You do not want to place a laying yard in any location that necessitates carrying the logs over any great distance, unless you are looking for a really good workout, or have a tractor or four-wheeler to transport them.

Proximity to Water and Water Source

A water source is necessary for forced fruiting (shocking) as well as for maintaining a threshold moisture level in the logs. Take into consideration how close and convenient each possible water source is. Particularly think about moving materials through the laying yard and common use patterns. If there is a dry spell and the logs must be wet down to maintain moisture levels, logs may be submerged under water for a few hours or wetted under a sprinkler for several hours. It is critical that the moisture content of the logs does not fall below a threshold necessary for the survival of the growing mushroom. Logs typically begin at about 40 to 45 percent moisture content and should not drop below 30 percent.

Ideally the water should come from a well, stream or public water system. Shocking is most successful when there is a significant temperature difference between ambient air and water for shocking. You can't control air temperature in the woods, but you can choose a laying yard site that will have access to clean, cold water.

Other Considerations

Other important aspects of the laying yard include slope, microclimate and

EXPERT TIPS & TRICKS: *What Makes a Good Laying Yard*

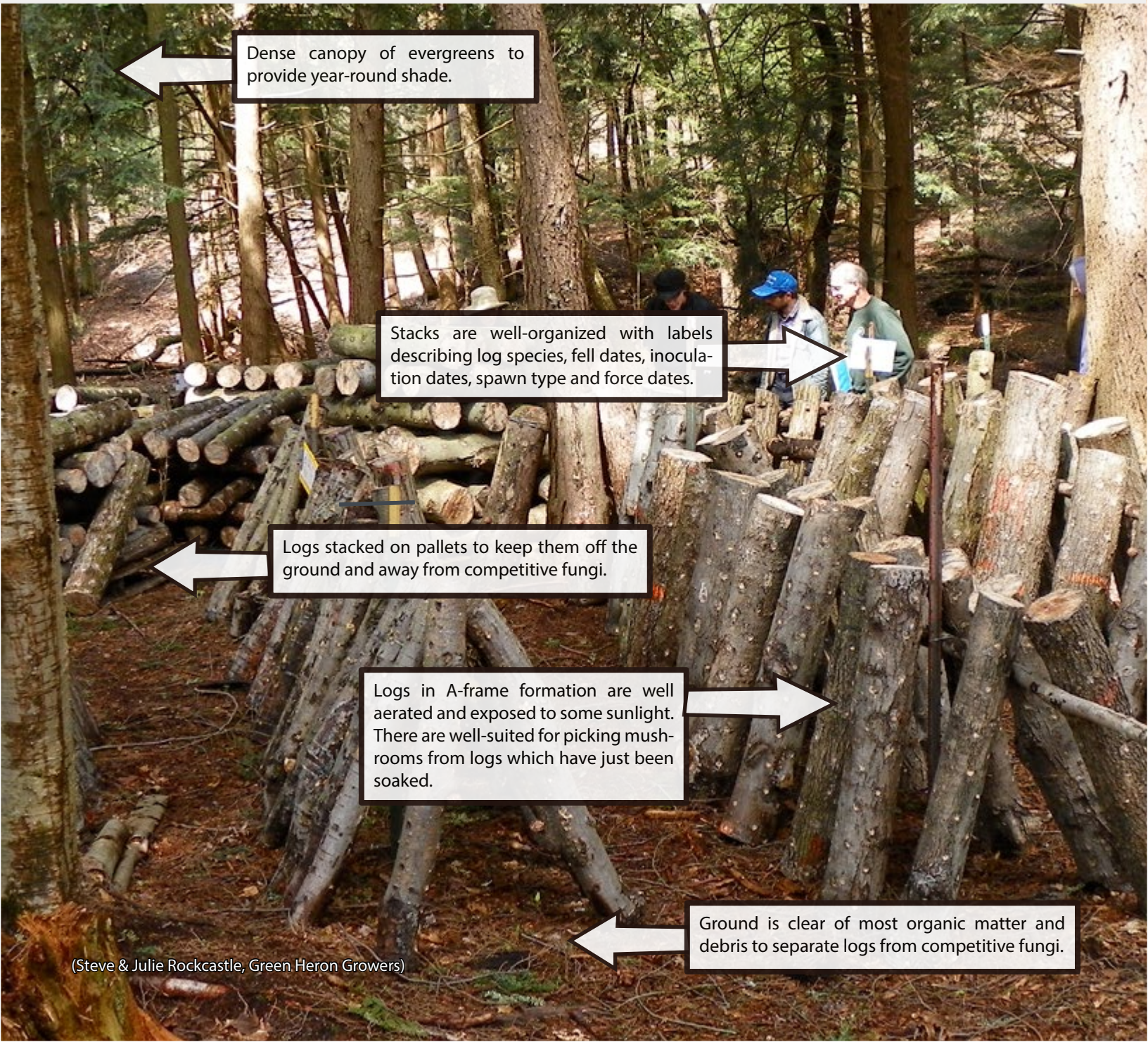
"I do make it a priority to clean up organic debris primarily around my fruiting area and have noticed (subjectively) that this has cut down on slug damage. In some of my fruiting areas I have laid down gravel which the logs lay on when they are fruiting ... further seems to help with slugs.

"I don't worry about organic matter where logs are not fruiting. I also find that there is enough air circulation even with shrubby undergrowth so only have cleared what I need to. I also get my log stacks off of the ground with locust as it is plentiful on my place and does a great job...but many things would work.

"For A-frame set-up I generally plan on about a foot of run to give me room to fruit 2 logs. So if you force 20 logs allow at least 10 feet of run...add a little extra just to add some breathing room."

- Steve Sierigk, Hawk Meadow Farm

Below is a laying yard at Green Heron Growers.
Note the characteristics that make a successful and productive laying yard.



(Steve & Julie Rockcastle, Green Heron Growers)

accessibility. The slope and microclimate of the laying yard will affect how you lay the logs. For example, if it is a site with lots of exposure to wind, one may choose to lay logs closer together to maintain log moisture. In the meantime, you might consider planting a windbreak. It is very important that the laying yard is accessible so that you may irrigate the logs if desired and check for fruiting regularly during the growing season. If it is necessary to incubate logs on a steep slope because level land is not available, the Japanese hill stacking method described below is worth considering.

Incubation Period

After the logs are inoculated, they must go through an incubation period or "spawn run" during which the fungus colonize the wood. During this 8- to 18-month period, the fungus colonizes and decays the log.

This doesn't mean you can forget about your logs for years; you will need to maintain favorable conditions for the shiitake mycelium so it can spread through the logs as quickly and evenly as possible. This could include maintenance soaking to keep log moisture content well above 30 percent. Artificial shading may be necessary if the laying yard is under a deciduous canopy. At the same time, you will need to protect the logs against competing fungi. Your final productivity will largely depend on how well the shiitake fungus establishes itself during spawn run, which in turn keeps competitive fungus at bay. Providing optimum growing conditions at this time is crucial!

Stacking the Logs during the Incubation Period

EXPERT OPINION: ***Crib Stacks***

"Keep production stacks as loose crib stacks that you can get your hands into to harvest shiitake that randomly pop up."

-Steve Sierigk, Hawk Meadow Farm

After the logs are inoculated, most growers place the logs in a crib stack. Crib stacks are simple and quick to make. First, four or five logs are laid down on a flat surface, then four logs are placed on top of them in the opposite direction, turned 90 degrees (or perpendicular to) the first layer. The pattern is continued for about five levels. The space between the logs in any layer should be 1 to 2 inches to assure proper aeration and allow leaf litter and other debris to fall through the stack over time. Crib stacks are a very space efficient way to keep logs as they make use of vertical space, compactly storing large numbers of logs. This stacking method is excellent for the spawn run period.

(Drawings by Carl Whitaker)

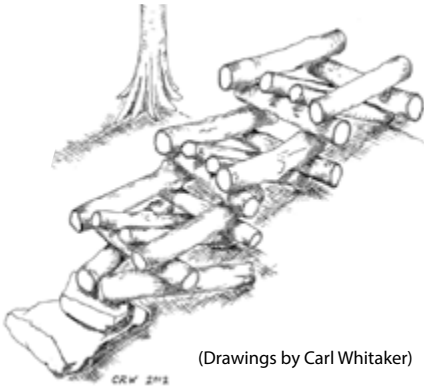
We recommend keeping the logs off the ground. Find some free pallets, dimensional lumber, or clean freshly cut logs, and use them as the base for each stack. Also helpful is to put larger logs on the outside and smaller ones on the inside, and to keep the stack balanced as you build up.

If you would like to store logs on steep hillsides, you may want to consider the Japanese Hillside Method. This stacking method is more complex

EXPERT TIPS: ***Hillside Stack***

For more information on this stacking method see "Our Cultivation Guide" featured on the Northern Mushroom Growers website at *http://mushrooms.cals.cornell.edu/*.

to set up, and only recommended for steep hillsides. This technique creates a very stable, aerated stack in which mushrooms are highly visible and easy to pick. The majority of logs are also raised off the ground, potentially reducing slug damage.



(Drawings by Carl Whitaker)

Moisture Management

It is important to ensure that the logs stay moist during the incubation period. Shiitake spawn cannot survive in logs that have a moisture content (the amount of available water in the log, expressed as a percent of the fresh weight) of less than 23 percent. Ideal moisture conditions for shiitake growth are log moisture content is 35 percent or more.

EXPERT OPINION: ***Maintenance Soaking***

"As a rule of thumb I would recommend 2 maintenance soaks during the initial spawn run. A minimum soak of 2 hours for all logs in the spawn run in early July and mid-August should keep your shiitake mycelium humming along nicely in most years.

"If your logs from last year are quite a ways from forcing I certainly would give them a maintenance soak during long bouts of hot dry, hot weather. My own yard is very protected from wind and direct sun so I don't worry much about maintenance soaks especially once I have started forcing cycles in early June. However, if your laying yard is less than ideal with sun and wind factoring in more, you may want to do a maintenance soak ... but do keep these soaks very short (1 to 2 hours) to not trigger a flush. When logs are 4 weeks out from a forcing, I empty my soaking tanks weekly on stacks (buckets of water method) that are a month away from a forcing to give them an artificial rain shower. My soaking tanks hold about 12 to 14 logs comfortably so it is a good way to hydrate logs quickly if I am in the yard for a few hours. "

- Steve Sierigk, Hawk Meadow Farm

"We have never done maintenance soakings. We have used sprinklers once in 5 years. Too many other things to do and too many logs! Maybe some logs have dried out earlier than they might have otherwise. Hard to know. We get three good years out of our logs, two flushes a season."

- Steve and Julie Rockcastle, Green Heron Growers

Shade

Keeping the logs shaded during the warm summer months will help maintain higher levels log moisture. Keeping logs shaded or snow covered during winter will ensure that the typically dry winter air does not dry out the logs. An evergreen canopy will shade the logs year-round. A thick deciduous canopy during the summer months will generally suffice, but a shading strategy needs to be employed for months with no leaf cover.

This can vary from a structure covered with shade cloth (70 percent), or simply by covering the logs with shade cloth. Professional greenhouse shade cloth is ideal, but burlap will suffice. Do use an opaque covering. If shade cloth is draped over crib stacks during winter, care should be taken to remove shade cloth when temperatures rise in the spring, to avoid drying and encouraging competitive fungi to grow under the cloth or tarp.

Log shaded by an structure covered in shade cloth. (Bill Stack, Cobb Hill Farm

Moisture Maintenance

In addition to keeping the logs shaded, you may want to consider dousing them with water occasionally during warm, dry summer month. This could be accomplished either using a simple hose and sprinkler system or a good soak for at least several hours is generally enough. If the logs are primed this might actually trigger a flush, so keep an eye on them after soaking. Expert growers recommend limiting maintenance soaks to no more than two hours. See sidebar on left.

It can be difficult to know when to initiate a maintenance soak. You can measure the moisture content of the log by cutting off a section of the log (known as a cookie), weighing it, drying it over 12 hours, and reweighing it. The moisture content of the log will be equal to the weight of water that evaporated during drying (wet weight minus dry weight), divided by the wet

weight. [%M = FW-DW/FW]. You could use this to judge the necessity of a maintenance soak. However this process is very time consuming and is not often appropriate for commercial enterprises. Moreover, profession electronic moisture meters designed for the forest products industry are not a reliable way to determine log moisture content for mushroom logs.

Instead, most experts decide whether or not to initiate a maintenance soaking based of the age of the log, tree species, weather and laying yard conditions. When deciding for yourself when to perform a maintenance soak, keep in mind that different wood species seem to retain moisture better than others. Red oak logs hold their moisture fairly well; bitternut hickory logs lose water much faster. It's important to use your personal observations and intuition in determining when to perform maintenance soakings.

EXPERT TIPS: ***Putting it all in Perspective***

"For perspective I look back in amazement at my first group of 100 shiitake logs I did back in the 1980s. I had way too many projects going on at the time and these logs were left to their own fate. In retrospect the laying yard was crummy ... a hardwood forest that let too much light and wind in. I never ever soaked these logs.

"These logs amazingly produced shiitakes for eight years, generally one flush per year before we gave up on them. Even though this was an impractical set-up it taught me that the logs are very resilient.

"Now since I am trying to rely on a weekly harvest promised out to restaurants, I try to keep the logs humming along as best I can without going crazy about maintaining moisture content. I always remember my early logs and know that disaster will not ensue if I just don't have the time to water. "

-Steve Sierigk, Hawk Meadow Farm

Contamination by Competitive Fungi

Excerpt by Steve Sierigk, Hawk Meadow Farm

Avoiding Contamination

Fungal competitors of your shiitake logs are always an issue even with the best management. It is impossible to block other wood-inhabiting fungi from the logs used in outdoor shiitake cultivation, because the spores of competitive fungi are naturally carried in the air. These spores can quickly establish a new colony when exposed to a suitable substrate under favorable conditions. However if the growing environment is properly managed, pest fungi should not present a serious problem.

Good timing of log felling and timely inoculation can help minimize fungal competitor access to your logs. If logs are felled in late winter or early spring, fungal competitors are minimized. Keeping logs stacked out of direct sun and wind will keep internal moisture content of logs high. At the same time, keeping log surfaces relatively dry is helpful as competitive spores can gain a foothold. Timely inoculation can also insure that your shiitake is the initial colonizer of the log, a great reason to get on to inoculation early. The lower temperatures of early spring also retards the growth of competitive fungi.

There are ideal circumstances and then there is reality; it is not always the case that we get to inoculate all of our logs in the early spring. It is sometimes the case that other fungal competitors get a toehold in to some of your logs. One important factor when inoculating and prepping your logs is to try to minimize especially the amount of direct strong sunlight that hits your log surfaces. Especially dark-colored barks can heat up in the sun and destroy mycelial growth, so take care to not expose your logs to excessive sunlight especially later in the season. Competitors such as hypoxlyon are favored by such conditions.

EXPERT TIPS: ***Fungal Competitors***

"Growers should be aware of the fungal competitors that are out there, some basic ID tools, and ways to minimize their occurrence. Even if you notice competitive fungi growing on a log, don't lose hope; ultimately shiitakes will probably still hang in there to some degree. Hypoxylon seems to be the worst and can be largely avoided by avoiding excessive exposure to direct sun for extended periods."

-Steve Sierigk, Hawk Meadow Farm

EXPERT TIPS: *Trichoderma Treatment*

Determining if the trichoderma is penetrating into the wood is not as easy as it may seem because the mycelium is white (like shiitake), not green – only the spores are green, and the fungus does not sporulate within the wood, so don't expect to see green wood.

What are some Northeastern growers really doing about tricoderma? Two references do not prescribe any action or treatment, two references say that you should increase ventilation and reduce humidity around the logs, and the last two references state that you should remove the infected logs, with one of those stating that the logs should be destroyed. Many growers are also spraying infected logs with 5 percent hydrogen peroxide to kill the Trichoderma on the surface of the bark so that spores won't be produced and released into the air to infect new logs.

EXPERT TIPS:
Conditions that favor Competitors

"As far as competitors go ... I feel like hypoxylon got a foothold during the 2012 spawn run in some of my logs as I was inoculating late into the season and it was so hot and dry. I have read that hypoxylon is not compatible with shiitake colonization and have taken these badly affected logs out of the yard ... some have minor shiitake colonization but are not worth managing. I have had minor amounts of hypoxylon pop up over the years especially in one of my yards that gets a bit too much sun. Also split gill fungus seems to have been a problem on my oak logs that also got too much sunlight during the late attempts at inoculation…shiitake and split gill somewhat coexist but it seems to really reduce yields. All the more reason to get on inoculation early. "

-Steve Sierigk, Hawk Meadow Farm

Fungal Competitors

Sometimes conditions are ideal and fungal competitors still become established in your logs. If this is the case, all is not lost ... and your logs, in all likelihood, will still produce shiitakes. The shiitake mycelium can coexist with competitors to some degree and although we cannot offer you a definitive treatise on how to deal with these competitors, we can suggest that you continue to care for your logs. It is often the case that your logs will still produce shiitakes although their ultimate production may be somewhat compromised. However if any production log does develop a serious fungal competitor you may consider removing it from your yard to decrease its chance of spreading unwanted spores.

Below, we have described a small sampling of some of some of the most common competitors you will encounter.

(1, 3, 5 - Steve Sierigk, Hawk Meadow; 2,4, -Steve and Julie Rockcastle, Green Heron Growers

1 Black Bulgur, Bachelor's Buttons or Rubber Buttons, Black Jelly Drops or Poor Man's Licorice *(Bulgaria Inquinans)*

This odd-looking mushroom resembles black gumdrops or cups. This fungus grows in groups, most commonly on felled oak trunks and fallen branches, and occasionally on other dead hardwoods including ash. This fungus may appear soon after inoculation entirely covering the log. There is often little advance sign that your log is colonized with this fungus. Be assured, however, that the shiitake mycelium generally establishes itself well in such logs; generally the black bulgar dissipates after about a year and the shiitake establishes itself well. It competes directly with shiitake to be the first to colonize the log for nutrients, but will not attack the shiitake mycelium itself.

2 Trichoderma (*Trichoderma longibrachiatum*)

Tricoderma is a green mold which grows on the end of logs. It is a mycoparasite (feeds on other fungi) and hence is a potential concern. This fungus occurs when the logs are exposed to direct sunlight for at

least one day. It may cause damage by producing antifungal compounds that lead to the cessation of shiitake mycelial growth. Warmer temperatures or low moisture content inside logs can lead to high populations of trichoderma inside the logs.

Hypoxlyon (*Hypoxlyon truncatum*)
Direct sunlight hitting the logs is conducive to hypoxylon development. Direct sunlight falling on the bark of shiitake logs can raise the internal temperatures to levels which inhibit shiitake growth. Hypoxlyon competition over shiitake is favored when the log is fairly dry which is a good reason to keep your logs well hydrated as described above. It competes directly with shiitake to be the first to colonize the log for nutrients, but will not attack the shiitake mycelium itself.

Turkey Tail (*Coriolus versicolor*)
This mushroom is easily distinguished by concentric rings of brown, rust, and black zones. It competes directly with shiitake to be the first to colonize the log for nutrients, but will not attack the shiitake mycelium itself.

Split Gill fungus (*Schizophyllum commune*)
A very common fungus has a shell shaped with white gills. Prefers dry conditions, especially favored when direct sunlight strikes during the hot, dry season. It competes directly with shiitake to be the first to colonize the log for nutrients, but will not attack the shiitake mycelium itself.

There are a few other competitors you may encounter but these are perhaps the most notable ones.

Forcing Bolts

Forcing is a matter of speeding up Mother Nature. Any log that has completed the spawn run and is well colonized with the shiitake fungal mycelium will fruit spontaneously under the right conditions albeit sporadically (unpredictably). But that may not satisfy a grower who needs a bunch of mushrooms within a short period of time (called a flush) to take to market, or for an upcoming picnic or dinner party. Fortunately, shiitake is one of the few mushrooms that can be made to "fruit" on demand. That is done through a process called forcing triggers the mycelium to produce fruiting bodies (mushrooms) predictably, within a short period of time. "Shocking" is how it's done. Shocking involves soaking logs in cold water for an extended period of time (12 to 24 hours) to induce fruiting. By shocking your logs on a schedule, you can generate a steady supply of shiitake mushrooms on a predictable rotation. See comments on page 31.

Logs should be stacked in the laying yard so they are easily identified in order to establish a schedule for shocking and harvesting. A shocking schedule should be developed which specifies how many pounds of mushrooms are needed and when they are needed (see example on page 32).

Based on this you can plan how many logs to force with each scheduled shocking, the number of times each log will be forced per season, when logs will be forced, how logs will move through the laying yard, when mushrooms are needed, when mushrooms are predicted to be available, and finally, when logs will be retired at the end of their lifetime.

When to Start Shocking

When to start shocking depends on the strain and log species. One option is to observe the mycelium growth (white discoloration) on the end of the bolt (see sidebar on page 23 for more information). When mycelium is visible on most of the bolt end, the bolt should be ready to fruit. Some logs might not have white mycelium visible on the log end but might still be ready to fruit. Generally, smaller diameter logs and warm weather spawn run are ready to

EXPERT OPINIONS: *Natural Fruiting*

"Logs will naturally fruit after periods of heavy rains or wide temperature fluctuations. In general, cold weather strains have a greater tendency to fruit naturally compared to warm weather and all-weather stains. Your choice to either fruit the log naturally or to shock/force the log under a rotation depends on your goals.

"Natural fruiting is certainly less labor intensive but shiitake production per log is much lower and lacks control over when the logs fruit. This can lead to shortages especially during the warm summer months, and surpluses during cool or especially wet periods. Be aware that if fruiting begins during a rainy period, the mushrooms become fairly water logged, increase their weight, and lose quality."

- Ken Mudge, Cornell University

EXPERT TIPS: *Start Shocking*

"I like to start my forcing regime after logs have produced their first natural flush."

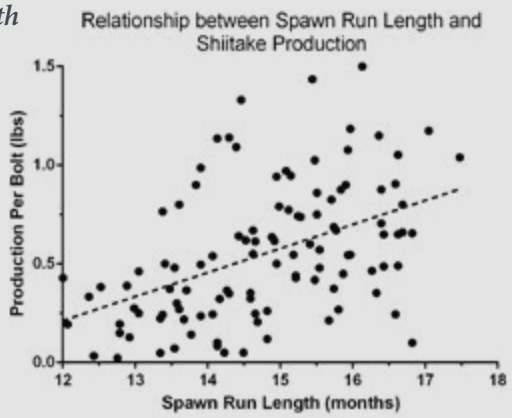
Steve Sierigk, Hawk Meadow

"I often try a smaller test soak to see where WR logs are at in terms of response and will often try a dozen logs ... if no response it was just a good soaking. Last year I tried a mid-May test soak with my WR logs ... no response ... but the following week worked and from then on I started my forcing cycles. This year is definitely ahead of last year.

Steve Sierigk, Hawk Meadow

RESEARCH: *Spawn Run Length*

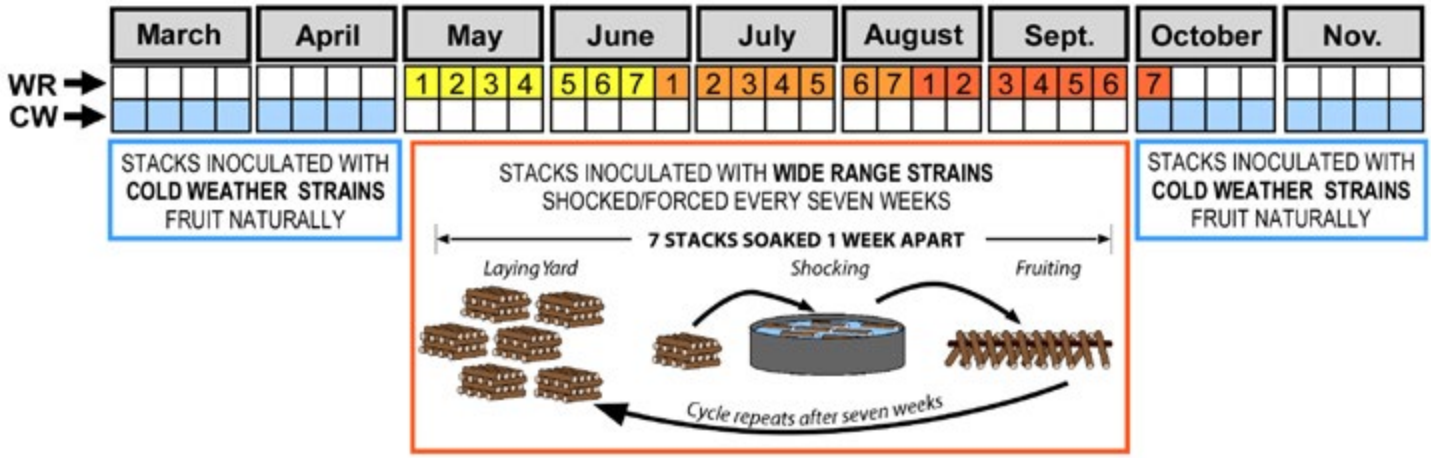
Those who waited longer prior to shocking were rewarded with significantly greater shiitake production. Although you can shock after 12 months, it might advisable to wait a bit longer - perhaps 14 to 16 months.



EXPERT TIPS & TRICKS *Maximizing Year-round Harvests*

Described in detail below is the strategy used by Steve Sierigk of Hawk Meadow Farm for maximizing shiitake production through a combination of (1) season extension using cold weather shiitake strains and (2) aggressive forcing schedule during the warmer months wherein seven groups of logs are soaked one week apart.

Each color in the WR row (yellow, pink, light blue) represents one 7-week/7-stack cycle. Blue represents fruiting of CW strain which doesn't get soaked. Chart shows that with WR 46 only the season would be only approximately 5 months long, but with both WR 46 and CW strain season would be an additional 3.5 months longer.



SEASON EXTENSION

During the cooler months (March, April, October and November) logs inoculated with cold weather strains are allowed to fruit naturally without being soaked.

Cold weather strains fruit naturally during the transition times from spring to summer and summer to fall. Northeast-based growers can inoculate some bolts (particularly large, heavy bolts) with enough cold weather strain to supply late spring and fall markets. These logs (displayed in the diagram above in blue) are allowed to fruit naturally during March and April, and October through mid-November. This enables one to obtain mushrooms an additional 3.5 months.

AGGRESSIVE FORCING SCHEDULE

During the warmer months (May, June, July, and August), groups of logs are forced by soaking them every seven weeks. In this example, the production logs that are to be fruited, are divided into 7 groups. The first group is forced in week 1, and then set out to rest. The same for the 2nd, 3rd up to the 7th group successively at one week intervals. By the time the 7th group has been forced on week 7, the first group has rested for 7 weeks and is ready to be forced for the 2nd time on week 8, follow by the remaining groups at 1 week intervals. This cycle may be repeated two or three times depending on the length of the production season.

The length of the forcing season depends on the weather; when using a wide range spawn, we recommend beginning once the temperatures reach 70. Depending on your region, you'll likely have 18- to 20-week time period. Many stacks will be forced 3 times in a season while some stacks may be forced twice.

Shiitake mycelium requires 40 days of carbohydrate metabolism to support the next flush of mushrooms after the last flush, although this time period may be flexible under different temperature and moisture regimes. Although a grower could push the forcing stacks to be flushed every 6 weeks, we recommend adding the extra week just to be on the safe side that the logs will really be ready.

OTHER FACTORS

You may also want to consider other factors like strains, and log ages when laying out your yard. Bolt stacks are often dynamic entities; consider culling out unproductive logs while adding newcomers to the forcing group. Managing the laying yard in a way that allows growers to rotate logs will allow them to consistently provide shiitake throughout the growing season to their prospective markets. Knowing when logs were inoculated, when they were shocked, and when they were harvested is extremely important to maintain consistency.

be shocked sooner than larger logs and cold weather strains. Also, nighttime temperatures should average above 50 degrees Fahrenheit before logs are shocked.

Most growers end up shocking after about a year. But you may find the logs aren't ready yet or that the first flush is small. The size of the flush depends on how much spawn was placed in the log during the inoculation phase, how moist the logs were kept, and how much competitive fungi exist in the log. If your first flush is small, don't despair -- try again about two months later.

Where to Shock

Place the logs in the coldest water available — a 100 gallon cattle trough or big tub works best. Because temperature adjustment is not practical, we recommend filling the tank from a fast moving stream or keeping the tank out of the sun. Rainwater collection is also a possibility. Ponds work well, though they may make log retrieval difficult.

Soaking logs in a 100 gallon tub.
(Rockcastles, Green Heron Growers)

Soaking logs in a pond.
(Nicholas Laskovski, Dana Forest Farm)

How to Shock

Submerge the logs in water for 24 hours. In general, logs left in the water for a longer or shorter amount of time will not reach their production potential. However, many growers may choose to vary the duration of the soaking based on the air temperature, log species and age of log. (See the side bars for more information.)

When you remove the logs from the water, stack them in an A-frame (conducive to the upcoming harvest). A high A-frame consists of logs leaning upright on one or two sides against a supporting beam, such as a cut sapling lashed horizontally onto two trees or a taut wire. This stacking method works well for the fruiting and harvest stages. Logs are well aerated, mushrooms are

Logs stacked in an A-frame formation in preparation for fruiting.
(Steve & Julie Rockcastle, Green Heron Growers)

EXPERT TIPS: *Chlorinated Water*

Some growers may be concerned about the chlorine in their water system and its impact on shiitake spawn; most have found that city water does not affect production. However, it is possible to off-gas the water used for shocking for 24 hours to reduce any risk by simply leaving the water uncovered for 24 hours.

EXPERT OPINION: *Warm Weather Forcing*

"In general I force logs at all times of the year for 24 hours ... but I have read that when the weather is warmer you need shorter soaks to trigger the forcing response while in the spring and fall it takes a longer time period to trigger the same response."

- Steve Sierigk, Hawk Meadow Farm

EXPERT OPINION: *Twelve Hour Soak?*

"Essentially, the greater quantity of water absorbed the better, during your forcing soak. With that being said, we were unable to see statistical differences between 12- and 24-hour soaks of the same tree species. So what does all this really mean?

"You could probably get away with a 12-hour soak, if you are using logs that take up moisture very easily, such as Carpinus sp., whereas a Red Oak or Sugar Maple, which takes water up at a slower rate than Carpinus, may need more time in the bath tub. When looking at yields, one very important predictor was total water absorption."

-Bryan Sobel, Cornell University

EXPERT OPINION:
Forcing After a Natural Flush

"If only a few mushrooms have popped out naturally, I generally will force these logs after I pick the mushrooms. Instead of a full 24-hour soak you can just do a shorter soak to keep the mycelium humming (4 to 6 hours) ... this should be enough to trigger a flush.

"If it is a significant number of mushrooms (like more than let's say 6- to 10) I somewhat consider that a flush and wait about 7 to 8 weeks to force again. "

- Steve Sierigk, Hawk Meadow Farm

EXPERT TIPS:
Frost and Rain while Fruiting

EXPERT OPINION: *How Often to Shock*

"I suggest trying to fruit your logs as often as possible from an economic standpoint, within the understood guidelines of the spawn regeneration/resting period. If your logs are still producing and a market still exists, you'd be maximizing your production. While the overall years of your logs may possibly diminish, you're reducing the risk of external failures over time such as drought, pests, other fungi, etc. It's up to the farmer to be very efficient with inoculation and maintain consistent shiitake production a goal to overcome the high cost of labor and sustain operations."

- Nick Laskovski, Dana Forest Farm

easily visible, and picking is easy, as there is maximum access to each log. Because logs stacked in A-frames take up a lot of space in a laying yard, they are usually not left on the A-frame for any other part of the process; this is especially true for a forced production model.

Mushroom sequence created from images taken 24 hours apart from initial pinning until harvest.
(Earl Tuson, Red Manse Farm)

Protect Mushrooms during Growth Phase

In 3 to 5 days, the log will begin pinning; Look for bumps about the size of a pencil eraser. At this point, consider protecting the mushrooms from high winds and cold weather, which can dry the mushrooms and inhibit their growth. Mushrooms exposed to freezing conditions during growth may either stop growing or develop an unfavorable texture.

Also try to protect budding mushrooms against rain storms, particularly 2 to 3 days before picking. Rain causes mushrooms to become soggy and waterlogged. Wet mushrooms are significantly less valuable; many growers discount the price by 20 to 25 percent, if they sell them at all.

Professional growers recommend covering your logs with fruiting blankets, agricultural cloth, or tarps to keep the mushrooms from freezing and getting more wet. Different types of cover may also reduce the potential for insects and other pests to damage the newly fruited shiitake mushrooms. Read more on each of these practices on page 35 and 36.

Logs stacked in A-frames covered by agricultural cloth
(Bill Stack, Cobb Hill Farm)

How Often to Shock Bolts

After fruiting, logs need to be rested for 6 to 8 weeks before being forced again. The more often the logs are shocked, the shorter their lifetime is likely to be. Experienced growers recommend trying to fruit your logs as often as possible (two to three times a year) for the following reasons[1]:

- It keeps the logs well hydrated, therefore there is little need for maintenance soaks in between forcing.
- It minimizes the probability of resting stacks producing mushrooms spontaneously (which are hard to pick).

1 Text adopted from conversations with Nick Laskovski of Dana Forest Farm and Steve Sierigk of Hawk Meadow Farm.

- It optimizes the ultimate yield of shiitakes from logs by reducing the probability that external factors (drought, pests, competitive fungi) negatively impact production.
- It imposes a sense of order to stacks of logs so that they can be easily managed each week.

For more information regarding how often to shock logs, see the expert tip on page 31.

EXPERT OPINION: *Culling Logs*

"We cull logs based on what year they were inoculated and cull a whole year's worth of logs at a time after the 3rd fruiting year. Unlike some growers, we do not mix new logs in with older logs. We keep each crib stack of 20-25 logs together as a group from inoculation till they are culled. We want to observe & record harvests per year and per strain to track productivity and monitor longevity. It's hard to give up on logs, so we put the culled logs in an area out of the way for their 4th year and get a few mushrooms from them, but the following year they are used for our festival bonfires. Another thing we do differently is to keep the logs in crib stack for the incubation year and then set them in A-frame formation the next spring and do not ever put them back in crib stack. So far, room to do this has not been an issue and this method saves labor moving logs after fruiting. "

- Steve and Julie Rockcastle, Green Heron Growers

Culling Unproductive Logs

Excerpt by Steve Sierigk, Hawk Meadow Farm

When you are first starting to build the size of your shiitake yard, and your inoculated logs are still young and productive, it is not always easy to think about culling out unproductive logs. It is not easy to give up on logs that have served you well, but there comes a time when your labor in moving logs around is not justified in log productivity.

Create a criteria outlining when you might start to pull logs out of your active forcing cycles. You will notice at some point that forced logs start to produce shiitakes sparsely and of much smaller size: it may be time to give up on these logs. Logs will also have a spent look; losing bark, losing weight, starting to get more competitors and starting to get punky. For instance if you introduce 100 new logs into your yard each year and force all logs twice a year, by year four you will expect to see signs of your first log burnout.

There are no hard rules for how to deal with these logs. One option is to leave them in a transition area for one year with no active management; expect to pick occasional mushrooms off some of these logs. Experienced growers also recommend using them around garden borders (you may even pick occasional shiitakes from these too). Some growers also burn spent logs in woodstoves as a heat source.

What will it take to shock/force 100 logs for 1 full year?

8	$34	Tarps Water Tanks Hoses
Hours of Labor	Worth of Supplies	

*Values based on data collected from 17 farmers starting a shiitake operation

EXPERT TIPS & TRICKS *Many Uses of Agricultural Cloth and Tarps*

Crib stacked logs covered by agricultural cloth.
(Ross Conrad, Dancing Bee Gardens)

WIND AND COLD PROTECTION

"Agricultural Cloth moderates the effects of weather on developing mushrooms. Developing mushroom pins can desiccate even in protected sites from the effects of sun and wind; agricultural cloth draped over pinning logs can protect mushrooms from sun and wind without effecting mushroom quality. Be aware, however, if it is raining that ag cloth offers no protection from getting soggy mushrooms so you might want to use plastic tarps to cover logs in these situations.

"When it is cold, I generally cover logs with a fruiting blanket or tarp in the late afternoon and take them off again after it has warmed up a bit. I will use agricultural cloth (row cover material) during a forcing if there are steady winds as wind can especially dry out beginning pins. I don't mind keeping the ag cloth on for extended periods during the forcing because it lets light through and shiitake quality never seems to have changed when I left ag cloth on for entire length of forcing."

-Steve Sierigk, Hawk Meadow Farm

"Growing mushrooms outdoors on logs offers many challenges, but we growers have many tools to help stack the odds in our favor. I came upon using ag cloth early on in growing shiitakes and it has made our crops a lot more able to withstand many variables, especially weather. I recommend purchasing a high quality ag cloth as light weight ones don't hold up well and tear easily on logs; Agribon, available through Johnny's, is quite reasonably priced."

- Steve Sierigk, Hawk Meadow Farm

RAIN PROTECTION

"Although tarps are a great tool they can cause problems too. I don't like to use them more than I have to ... and have now generally favored the ag cloth if it is too hot or windy ... and only bring out the plastic tarps to keep off rain. I have also observed that keeping tarps on too long favors other shiitake competitors.

"I will use plastic tarps (I prefer clear plastic so I can see what is happening) when I see the threat of rain, especially being vigilant the 2 days before picking. Wet mushrooms are a bummer ... and I usually discount their price by 20 to 25 percent if I sell them at all. I don't like to leave plastic on longer than necessary because I have an intuitive feeling that these mushrooms don't develop as good a taste or color when under a tarp their whole time ... especially if tarp is very opaque ... they also seem to get on the leggy side and seem lighter in color to me. "

- Steve Sierigk, Hawk Meadow Farm

"White plastic is what we had amongst our farm supplies, so we started using it. First to cover fresh cut logs before inoculation and then to protect fruiting logs from rain. We cover logs only after they've been soaked and the mushrooms are about half grown. White plastic doesn't let much light in, so we don't get heat built up around the mushrooms. We have yet to try Agribon"

- Steve and Julie Rockcastle, Green Heron Growers

"Being able to cover your mushrooms prior to a heavy rain can help save a mushroom crop from becoming too soggy. Clear tarps tend to create a greenhouse-style effect on mushroom caps and should be used with caution based on direct sunlight and outdoor temperatures. When used, watch to make sure the logs/mushrooms are not overheating beneath the tarp."

- Nick Laskovski, Dana Forest Farm

"I've been using nursery grade shade cloth 80 percent and it's working wonderfully; tarps seem overly oppressive, and the shade cloth does well in sheltering from rain."

- Steve Gabriel, Wellspring Forest Farm, Mecklenburg NY

EXPERT TIPS & TRICKS *Many Uses of Agricultural Cloth and Tarps*

Fruiting Logs covered with shade cloth
(Matt Anderson, Tyrrel Mushroom Farm)

SEASON EXTENSION WITH FRUITING BLANKETS

"Fruiting blankets ... I bought a few of these from Field and Forest (they are fairly heavy duty and are black) and have experimented with these especially with spring and fall wide range forcings. After I take the logs out of the water and put them in A-frame picking position ... I first let the surface water dry off which will take perhaps an hour and then throw the fruiting blankets over these logs ... the hope is that these help provide a nice warm moist environment to give the pins a great start. I am still experimenting with fruiting blankets but think they help."

"Our general procedures are fruiting blankets when pins appear, keep moisture and temp up, but slugs like this too ... generally a day or 2 with these especially in cooler weather. I then switch to agricultural cloth as the pins grow to let in a bit more light but keep out wind. I keep an eye on the weather and if a rainstorm is due we do throw plastic tarps over the logs to keep the rain off as wet shiitakes are a bummer."

- Steve Sierigk, Hawk Meadow Farm

Fruiting Logs covered with shade cloth and agricultural cloth under a tarp structure.
(Bill Stack, Cobb Hill Farm)

PEST PROTECTION

"Another use of ag cloth worth mentioning is when newly inoculated logs are in a tight crib stack during the spawn run. Certain log species, like Bitternut Hickory, are particularly vulnerable to boring insects, primarily long-horned beetles, which bore into the logs. Ag cloth draped over the crib stack can discourage the adults from laying eggs into the logs in the first place.

Ag cloth also can help to keep pests off of developing mushrooms, especially if tucked in tightly. Some mammals such as red squirrels can develop a taste for shiitake and ag cloth is an effective tool to keep them off. All covering ... especially ag cloth ... seems also to help keep slugs at bay."

- Steve Sierigk , Hawk Meadow Farm

"The purpose of the Agribon is too keep the humidity consistent during pinning and fruiting, and it keeps out pests. I just drape Argribon right over the logs and it doesn't really interfere too much with growth. Sometimes I'll place a rock or old log on the cloth and pull it away from the logs. That keeps the cloth close to the ground and off any fruiting mushrooms. Agribon keeps my shiitakes safe from nearly all pest damage, except slugs.

"A few weeks ago I was looking for some advice on what turned out to be a pleasing fungus beetle attack. The infestation that I got had essentially wiped out 25 percent to 30 percent of my crop one week. The solution was ag cloth on the ground around the a-frames and then we covered the logs at all times with another type of ag cloth, called Agribon (row cover). That stopped the beetles to virtually no attack. However, a few manage to get in every now and then but they don't cause nearly the extent of damage as they were on the uncovered logs. This week I haven't seen one yet. The ag cloth also keeps the thrips to a near minimum. In the end, a constant covering of ag cloth results in nearly perfect mushrooms."

-Matt Anderson, Tyrrel Mushroom Farm

(Whole System Design, Mad River Valley, Vermont)

EXPERT TIPS: *What yields to expect and how to improve yields*

"As far as expected yields ... I think that it is somewhat predictable but has so much to do with many factors; inoculation, selection of good bolts and what tree species are used. A bolt does not always equate to a given amount of mushrooms. For instance my bitternut hickory logs give perhaps 30% to 50% of my oak logs and are a management dilemma (the timing of their production spreads out over a few weeks rather than a discrete, quicker time). I have some nice-looking red oak logs that have produced little as they were so slow growing that their sapwood layer is pitiful! I am really finding that the biggest factor in production is really nice bolts ... but oftentimes we are just working with material that we have at hand. Saying this however you can probably expect one-third to one-half pound per bolt per forcing ... you may get more or less. I have had great logs yield 2# or more per flush ... and I have also had dogs that produced little. If forcing 100 logs, 30 to 35 pounds each week is very achievable. This is one reason I will go out of my way to acquire superior material ... that is since we put so much work into management. But learning what is great material is perhaps part of the necessary learning curve. Also the reality of balancing what bolts we can easily get is part of the whole idea of this as management of our woodlots if we have them."

-Steve Sierigk, Hawk Meadow Farm

Common Mushrooms Pests and Concerns

Slug Damage

Slugs cause more damage to shiitake crops than any other pest. They are more common during cool, moist weather. There are many alleged remedies for slugs on Shiitake logs, but there is little agreement about which is best. Below, Northeast growers share their secrets:

Slug enjoying shiitake mushroom.
(Bill Stack, Cobb Hill Farm)

- *"I provide lots of toad habitat which I really believe can be good allies with slugs. Toads get to become recognized company (live up to 40 years) as they often keep to the same hangouts and you can start to tell individual toads apart. They do eat slugs ... although it would take a good-sized one to eat those big slugs."* -Steve Sieri gk, Hawk Meadow Farm
- *"I would go out every night "slugging" with a flashlight and a skewer. Over time there was much less damage."* -Sal LaFemina
- *"I rake under the ferns and leaf/needle litter to locate where they are hiding/resting during the day. Then I introduce my chickens to them. Slugs are a great chicken delicacy, it seems. After 2 to 3 days the problem is back to being manageable. "*-Carol
- *"We installed angular gravel in the fruiting area, which helps keep the area well drained for the moisture loving slug. We also use wood ash/charcoal, a by-product from our outside furnace, and Sluggo around the outside of the structure."* -Bill Stack, Cobb Hill Farm
- *"I've built a few simple gravel beds, framing them out with old lumber and filling with gravel (the sharper the better). It seems to be working quite well"* -Steve Gabriel, Wellspring Forest Farm, Mecklenburg NY *"When picking shiitakes, slug checking is just a part of the operation. We do specific slug checks when the shiitakes are developing morning and night. Sometimes this is just a quick 5-minute perusal but certainly after a rain it is more. We feel like it is worth it as otherwise we would lose perhaps 4 to 5 pounds of shiitakes each week to slugs."* -Steve Sierigk, Hawk Meadow Farm

Pleasing Fungus Beetle

The pleasing fungus beetle is about an eighth inch long with a hard red-brown body. Pleasing fungus beetles feed on the fruiting bodies of fungi. These pest can seriously disrupt a shiitake operation. If they are a problem in your area, we recommend covering fruiting logs with agriculture cloth (such as Agribon). See sidebar for more information.

Pleasing fungus beetle damage
(Matt Anderson, Tyrrel Mushroom Farm)

Squirrels and Chipmunks

If you notice that sections of your mushrooms have been eaten, squirrels may be the culprit. Growers have noticed that some squirrels eat the mushrooms while others simply break them off the log and nibble on them. Possible solutions are to cover fruiting logs with agricultural cloth, allow dogs to roam the laying yard, or trap and remove the offending squirrels.

EXPERT OPINION: ***Copper Wire***

"Our first forcing area we actually went as far a putting up copper wire encircling the area aground the forced logs ... but I have watched slugs cross over it and from what I have read you would need about a 2-inch width of copper for a slug barrier, impractical for most of us. "

-Steve Sierigk, Hawk Meadow Farm

EXPERT TIPS: ***Pleasing Fungus Beetle***

"Pleasing fungus beetles are rampant in the Hudson Valley. As soon as they realize that you grow mushrooms they move in, and they move in with a vengeance. The solution is to cover your logs while they are fruiting with an agricultural cloth. We use Agribon. Don't allow any access at all. Agribon is a product that has several advantages for growing shiitakes anyway. It prevents the pins and eventually the mushrooms from drying out. A lot of farmers use it."

-Matt Anderson,
Wood Advisory Services, Inc.

"Chipmunks are a pest in the fall for us and can take a whole bunch of shiitake pins in a few days. They are stocking up, we presume? We see little teeth marks on the logs where the pins were. We've also seen teeth marks up under the caps where chipmunks or mice have eaten their favorite parts. Harvest what you think is a perfect shiitake, but no, the critter got there first!"

- Steve and Julie Rockcastle,
Green Heron Growers

Harvesting Shiitake

When to Harvest

Shiitake mushrooms are usually ready to be harvested 7 to 10 days after shocking although colder temperatures will slow their growth. It is not the size of the mushroom that determines when it is picked, but its growth progress. Gills should be visible and the outer edge of the mushroom should be slightly curled under, but not tightly so. If the edge has flattened out, the mushroom is slightly over-ripe, but still edible.

Shiitake mushroom ready for harvest.
(Ben Waterman, UVM Extension)

Shiitakes are more marketable when the cap is still curled and somewhat closed. Wide, flattened mushroom caps indicate over-maturity and will not be as valuable as the fresher looking forms. Many growers choose to dry overgrown and damaged mushrooms, and report that pound for pound at fresh stage, dried shiitakes sell for just as much money as fresh. The advantage of dried mushrooms is they do not have to be aesthetically perfect, although it is suggested, especially for mushrooms sold at retail, that they be harvested at the right time and free of slug damage or other major defects.

Overgrown shiitake mushroom
(Photo Ben Waterman, UVM Extension)

For more information regarding how to dry the mushrooms, see the section on processing.

How much to Expect

Mushroom production for a typical log will peak the second and third years. At this time it is reasonable to expect 0.25 to 0.5 pound of mushrooms per log or higher per flush, with the goal of doing two shockings per season. Over the course of five years, you can expect to produce approximately 3 to 4 pounds of fresh mushrooms per log.

Removing and Cleaning Shiitake Mushrooms

When harvesting shiitake mushrooms, the goal is to efficiently remove the mushrooms without damaging the bark. Most experienced growers simply twist and pull the mushrooms off the log using their hands. See sidebar for more information. However, if you don't feel comfortable with this method, you can use either a curved pair of scissors or a knife in order to ensure a clean cut on the stem. Either way, growers make the point to "not worry" because a thoroughly colonized and well-managed log should be fine with minor pieces of bark removed.

Gently brush off any dirt or debris, without washing the mushroom under water, and place each mushroom into an open basket, paper sack or other vented container.

EXPERT TIPS: *Harvest Timing*

"On the cooler ends of the forcing season I generally allow 11 to 12 days from forcing to picking ... even more in the fall when I really seem to push that last forcing."

– Steve Sierigk, Hawk Meadow Farm

"I usually time my fruitings 10 days in advance of when I plan to sell them. If there are harvestable shrooms beforehand, I'll put them in the fridge for a day or so, collect more, and then deliver when the logs are fully harvested. "

- Nick Laskovski, Dana Forest Farm

EXPERT TIPS: *Picking Techniques*

"I pick by hand ... using both hands. I grab stem as close to base as I can and twist. I also notice a distinct difference between log species on how shiitakes pick ... some come off quite easily and some are more difficult ... so if I feel much resistance I often make sure to pull in a direction that goes against the grain of the wood ... this often minimizes bark tearing and makes a cleaner pick. "

– Steve Sierigk, Hawk Meadow Farm

"I used to cut the mushrooms off - until weekly harvesting began taking too long (one at time with one hand working the knife). I now harvest 'two handed' and carefully twist the stem to remove it cleanly without tearing the bark. Getting a knife behind every stem is not so easy when the mushrooms are in clusters. And watching highly experienced growers (even in Japan) work has shown me that cutting every one off is just too slow/tedious."

- Bob Wagner, North Woods Shiitake

EXPERT TIPS: *Thrips*

"Thrips ... tiny and fast-moving. The ubiquitous thrips are a nuisance but seem to cause little physical damage. After picking shiitake we gently blow on the gills and the thrips rise to the surface; gently tap the shiitake to send the thrips elsewhere, deal with as you will! Thrips seem to be worst in the warmer temperatures of summer."

– Steve Sierigk, Hawk Meadow Farm

Thrips

Thrips on shiitake gills
(Steve & Julie Rockcastle, Green Heron Growers)

Thrips, in the order *Thysanoptera*, are common to Northeast mushroom laying yards. These are tiny, slender black insects, about one eighth inch long, that feed on mushroom spores. They can be found crawling in the gills before harvest. While cumbersome to deal with, they are often not a cause for concern, because they feed on the spores and not the mushroom fruiting body.

A few light taps on the top of the cap is often enough to disturb the thrips so they dislodge and fall out. If the problem is more widespread, mushrooms can be harvested in bulk and blown, under light pressure, by an air compressor.

Deer

Deer-damanged shiitake caps
(Nicholas Laskovski, Dana Forest Farm)

Some deer may also acquire a taste for shiitake mushrooms. Spraying deer repellent around your laying yard should discourage the deer. Deer have not generally been considered a serious pest of shiitake, except in isolated incidents. One of the most extreme of these was reported recently by an experienced Vermont grower. Over a single night, what must have been a herd of deer ate hundreds of shiitake mushrooms from scores of logs, costing the grower hundreds of dollars.

Cracking Caps

Shiitake mushrooms with cracked caps
(Nicholas Laskovski, Dana Forest Farm)

Cracking in shiitake caps occurs due to the varying growing conditions, typically dry conditions, after the shiitake pins. In Asian cultures, dried shiitake cracked caps are highly valued (and priced/graded higher) because their flavor is considered more intense. These shiitake are often called "flower" shiitake as the cracking pattern resembles a blooming flower. Many growers in Asia deliberately try to induce this condition (high humidity and temperature during day and cold and dry at night) to achieve a higher yield of flower shiitake.

Large Stems and Small Caps

Shiitake generally develop large stems and small caps when there is not enough fresh air exchange and sunlight. To alleviate the problem, introduce more airflow and sunlight into your laying yard and fruiting structures.

EXPERT TIPS: *Overgrown Shiitake*

We typically eat overgrown shiitake mushrooms grilled with melted cheese and garlic as a sandwich ... we call these 'grillers'. Some of the restaurant accounts have said that they would not mind the overgrown ones if they are not in bad shape ... I would discount these a wee bit."

–Steve Sierigk, Hawk Meadow Farm

Overgrown Shiitake

When shiitakes become overgrown, the caps become wide and flattened. These mushrooms, although still edible, will not be as valuable as the fresher looking forms. Many growers choose to dry overgrown and damaged mushrooms.

In the fall and spring, logs have a strong urge to produce shiitakes due to natural environmental triggers, so it is good to walk through stacks every few days to look for them. We also recommend keeping your stacks loose enough that you can collect naturally fruiting mushrooms as they arise.

Overgrown Shiitake Mushrooms
(Ken Kelban)

Shiitake Look-a-Likes

It is critical for every grower to be certain that what is being picked and sold or eaten is actually Shiitake. Absolute care should be taken to only pick mushrooms from logs that you have inoculated and to make a positive identification for every shiitake mushroom that comes off your log. If you are ever unsure about whether it is shiitake, consult a university mycologist or other mushroom expert.

Gallerina is a small brown mushroom that grows on wood. It has a brown spore print, and is usually found on very decayed wood. It is very poisonous. It is pictured below on the left below. A shiitake mushroom and its white spore print is pictured to the right below.

Poisonous gallerina mushrooms
(Ken Mudge, Cornell Univesity)

Delicious shiitake mushrooms
(Steve Sierigk, Hawk Meadow Farm)

What will it take to harvest mushrooms from 100 logs for 1 year

8	$17	Scale
Hours of Labor	Worth of Supplies	Nails
		Gravel
		Knife

*Values based on data collected from 17 farmers starting a shiitake operation

Storage & Preservation

EXPERT TIPS: *Storing Fresh Shiitake*

Stainless steel hotel pans have become our preferred storage container because they are large and come in various sizes. To control moisture in the bottom of the pans we put down a layer of paper towel, but leave the top open. If we have to hold mushrooms a week or more, we'll transfer them to clean pans occasionally and replace the paper towels. This helps to make sure they have good air circulation around them, too. We use baskets in the fridge at times, but have found that the fiber baskets start to mold pretty quickly. Those are reserved now for harvesting. Paper bags don't work well for long, unless you deliver or sell your mushrooms the day or so after harvest. This, of course, is the best-case scenario! One factor that I don't think we'll ever be able to account for is shrinkage from dehydration in the fridge. What we harvest and what we sell can be quite different depending on how long they are refrigerated. That brings down the "income per pound" by some percentage unknown.

-Steve and Julie Rockcastle,
Green Heron Growers

"It's been my experience this year that wax-lined cardboard boxes are the best way to store mushrooms in the refrigerator. I have been getting boxes from my restaurants. They typically have several openings to allow air flow through the box during storage.

"One thing I've learned is not to put too many mushrooms in a box. For example, I can fit about 6 to 7 pounds in a typical box (15"x20"x4") and that's about it. Mushrooms keep very well in a fridge, if stored properly, with some air flow. If you overcrowd fresh mushrooms the bottom ones won't get any air flow and they'll head south sooner that you'd like them to."

- Matt Anderson,
Tyrrel Mushroom Farm

Mushroom Storage Techniques

Storing the fresh mushrooms

For a high-quality mushroom, it is important to get the harvested mushrooms into refrigerated storage as soon as possible, certainly within one hour of picking. These mushrooms will remain fresh and marketable for several weeks, if kept in a cool (41°F), dry and dark place. Do not seal them in an airtight container. A paper bag (not plastic) works very well. Keep in mind that mushrooms will dry out and lose weight the longer they are stored. See sidebar for more information.

Freezing Shiitake Mushrooms

Mushrooms need to be treated to stop maturation before freezing, usually by steaming or sauteing. Soak mushrooms in a mixture containing 1 teaspoon lemon juice or 1.5 teaspoons citric acid per pint of water for 5 minutes to reduce darkening. Steam whole mushrooms for 5 minutes, buttons or quarters for 3.5 minutes and slices for 3 minutes. Cool promptly, drain and package, leaving 1/2-inch headspace. Place small packages in the freezer for fast cooling.

Drying Shiitake Mushrooms

Dry shiitakes are an excellent way to bring seconds to the market. Any mushroom with cosmetic defects can be dried, but mushrooms that are molding or have excessive beetle or other damage that compromises taste should be avoided and discarded.

Drying can preserve large quantities of mushrooms up to a year. The dried mushroom has a moisture content of approximately 13 percent and weighs about one seventh the original fresh weight. Separate mushrooms by size and grade. Remove stems completely, as they harden when they dry. Place mushrooms on trays with gills up. Avoid allowing the mushrooms to touch each other.

Sun Drying / Outdoor Drying

Advantages: Low-cost, simple, increased vitamin D content in mushroom

Disadvantages: Depends on weather; can be slow process

Method: Spread the shiitake on shelves so that the gills are directly exposed to sunlight. You can also string them using thread or fishing

Drying shiitakes outsides.
(Bill Stack, Cobb Hill Farm)

EXPERT TIPS: *Drying Shiitake*

"One of the best uses of shiitake overage is dehydrating. We used to dry them whole, but now slice them, by hand. We leave as much or the stem intact that is soft and not woody. The labor required is a factor, but we slice them because our customers prefer them that way and because we can cut out damaged areas of perfectly tasty mushrooms. We had a "American Harvester" dehydrator that worked up until this year and now have an "Excaliber" with 9 trays. Each batch can start with 5-7 pounds fresh. The mushrooms overlap on the trays quite a bit, but reduce so quickly it doesn't seem to matter. A batch takes 6-8 hours at 95 degrees. Last year we dried 100 fresh pounds and got 14 pounds dried. We trying the oven a couple times at 200 degrees, but I'd say they were close to burnt and flavorless. We have also tried sun-drying in our greenhouse, but it took more than one day and we felt there was too much risk of insects contaminating them."

- Steve and Julie Rockcastle, Green Heron Growers

line and then hang and dry them in a breezy, dry spot. Length of time required will vary depending on the weather conditions.

Dehydrator / Home Food Dryer

Advantages: Simple process, quick drying time

Disadvantages: Energy intensive, only handles small quantities (2 to 3 pounds fresh shiitakes)

Method: Follow the instructions that come with the dehydrator. You have to ensure that you dehydrate your mushrooms until they are light and dry, but not brittle. They should be slightly flexible.

Oven / Thermal Drying

Advantages: Best quality, quick

Disadvantages: Requires special equipment and a fuel source

Method: Arrange the mushrooms on shelves with the gills facing upwards. The drying chamber should be maintained at 100-125°F for 24 hours. The mushrooms should then be cooled for one hour before being stored long-term. Once dried, the shiitake should be put into polyethylene bags, sealed and kept in a dry, cool, dark place. If drying the mushrooms in your oven, set the temperature to 200°F and keep the door ajar.

Value-Added Products

Value-added products can include dried mushrooms and any kind of cooked or baked product with mushrooms – a shiitake pâté or sauce for example. Value-added products can be a great way to diversity your income and increase your profits.

The production and sales of these types of processed foods is governed by state and federal regulations. Each state is different, so proper advice is needed from a specialist in each state. Some states allow sales at farmers markets of select foods; others prohibit sales altogether.

Depending on how much product you sell annually, , you will be required to process your product in a licensed kitchen. Home kitchens are not usually considered appropriate for processing purposes. In most states, in order to sell your homemade products on a commercial basis, you'll need to have your

Dried shiitake mushrooms
(Bill Stack, Cobb Hill Farm)

Shiitake tincture on display
(Rockcastles, Green Heron Growers)

kitchen meet commercial grade kitchen standards and pass a health department inspection, like a restaurant. The process of converting a home kitchen can easily cost upwards to $50,000. There are, however, ways around this:

Canneries and licensed kitchens

Prepare your batches in kitchen that is already licensed. Some people rent restaurant kitchens during their off hours and do the prep and canning there. In some cases, a local cannery is the way to go. If they are licensed as a commercial kitchen (and many are), then you will be able to avoid the need and expense to rent a restaurant kitchen.

Copackers

Copackers manufacture and package foods for other companies to sell. These products range from nationally known brands to private labels. Entrepreneurs choose to use the services of copackers for many reasons. Copackers can provide entrepreneurs with a variety of services in addition to manufacturing and packaging products. They can often help in the formulation of the product. The copacker may function only as a packer of other people's products or may be in business with his own product line. They may be, in fact, manufacturing several competing products. The range of services available from a copacker will vary depending on the size and experience of the copacker and the type of facilities and the capacity of their plant.

RESEARCH: ***Medicinal Properties of Shiitake Mushrooms***

Flavonoids, a class of chemical compounds found in foods, have received attention for their association with beneficial health effects in humans. The flavonoid concentration in shiitake mushrooms was found to be comparable to the peel of apples (the peel is the site of the greatest concentration of health promoting compounds). While the wives tale suggests that "an apple a day keeps the doctor away", it may be more appropriate to say that "a mushroom a day keeps the doctor away".

(Adapted from thesis research by B. Sobel (2013) of Cornell University)

EXPERT TIPS: ***Value Added Shiitake***

"We regularly have shiitake leftover from farmer's markets, that are still useful and flavorful, or mushrooms that have damage from pests, that we don't want to sell fresh. Also, sometimes the harvest is just more than we know what to do with, as a fresh product, and it's become our solution to preserve them. We have a separate kitchen from our home kitchen that is licensed by New York State Ag & Markets as a 20-C Food Processing Facility. In order to dry and then sell dried shiitake or cook them and make value added products; we must be licensed in NY State.

We have two great shiitake recipes that we make in large batches, then freeze in pint and quart deli containers and transport to farmers markets. One is Shitake Hazelnut Pate and the other is Shiitake Barley Soup. Both sell really well, especially when customers can taste test them! Sometimes we don't have time or supplies to make the end products and just slice 5 pound batches of shiitake, sauté them in butter or olive oil and freeze for later use. "Duxelle" is a simple sauté recipe that can be made in small batches for home use later on or to freeze and sell also.

Tincture made with shiitake is also a very successful product for us. An herbalist friend taught us how to make our first batch of tincture. Shiitake mushrooms are well known as a "super food", but they also have medicinal benefits. Shiitake mushroom tincture works as a deep immune system activator. Shiitake have been extensively studied for use against cancers and viral infections. Compounds found in Shiitake have demonstrated many other actions including liver protection, blood pressure & cholesterol lowering, and anti-fungal properties.

- Steve and Julie Rockcastle,
Green Heron Growers

What will it take to process mushrooms from 100 logs for 1 year

4	$30	Ingredients Dehydrator
Hours of Labor	Worth of Supplies	

*Values based on data collected from 17 farmers starting a shiitake operation

Marketing Forest-Grown Shiitake

Sales Venues and Pricing

Growers can sell their mushrooms at many different venues. You can receive the highest price per pound at farmers markets (approximately $15 to $20 per pound, depending on your location and distance from New York and other large cities). However, you'll also be required to spend more time selling the mushrooms. Most growers prefer to sell their mushrooms through direct on-farm sales (like a farmstand), grocery stores and restaurants; through these type of venues, growers tend to get a little less - approximately $12 to $13 per pound when sold in wholesale volume.

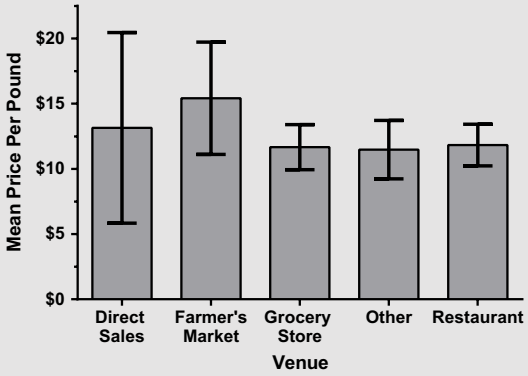
EXPERT TIPS: ***Develop a Local Market.***

"We took advantage of our local newspaper and had an article published this week. Free PR. When I stopped in the village to grab my daily dose of caffeine, I had four people tell me they saw the article and each were interested. I would recommend using your local papers for PR to anyone on this list."

-Matt Anderson,
Tyrrel Mushrooms Farm

RESEARCH: ***Price Per Pound***

On the right, you can see the actual prices which farmer's in the Northeast sold their mushrooms. Error bar indicates one standard deviation. On average, farmers sold their mushrooms for $13/lb. at grocery stores, restaurants and direct sales and about $15/lb. at farmers markets.



EXPERT TIPS: ***Pricing***

"I dropped off half a dozen pint containers (about 0.25 pound each) at a local farmstand owned by a friend of mine (in southern Sullivan County, N.Y.) which we priced at $6.50 (26.50 per pound), and they sold out in a few hours.

Steve Kosmacher

Ideas to Help Develop a Market

General Tips

- How to compete with $7 to $8 per pound sawdust-grown shiitake mushrooms? Keep communication open about the virtues of log-grown. Better taste, higher beta-glucan levels, superior freshness and shelf life, etc. Also, the process of growing log-grown can be highlighted. It is part of an overall sustainable forest management strategy, not just a production assembly line.
- Make sure that the mushrooms you are selling are always top quality.
- Try to be consistent with delivery times and quantities. If you have promised a certain amount of product, make sure your rotation schedule reflects this.
- Collect e-mail addresses and keep communication flowing. Certain customers will want to stay in the loop about your mushroom production and availability of different types of mushrooms (e.g., "grillers" vs. small caps for stir-frys).
- Some people prefer very large mushrooms for burgers and grilling, some

EXPERT TIPS: ***Product Labels***

Volume quantities do not need to be exact in terms of weight per volume sold, whereas products sold by weights need to have certified scales, according to some states' regulations. Weights can still be communicated, but it can be stated on labels or verbally that weights are rough. For example "one basket is roughly 0.25 pound of mushrooms.

EXPERT TIPS: *Farmer's Market Displays*

"We started out displaying our shiitake in nice baskets with a $16/pound sign, like in this photo. Sales were slow! We quickly switched to putting 1/4 pound in balsa wood pint baskets for $4 and 1/2 pound in quarts for $8. Much better! Next we quit bringing the scale to the market and wasting time being exact about weight and started selling by volume with pint and quarters for $4 or $8. Some days we have heavier/wetter mushrooms and we don't get our $16/pound, but it averages out just fine. A fun thing we like to do for markets is to bring a fruiting log for display. Kids love this and it starts many conversations! Sometimes the customer cuts the last pint of the day off the sample log. They definitely go home and tell someone about this."

- Steve and Julie Rockcastle, Green Heron Farms

EXPERT TIPS: *Working with Restaurants*

"When I approach restaurants, I bring along a small flyer that has photos of the logs so they get a sense of growing methods and also text which explains some generalities of log-grown superiority over sawdust-grown (taste, nutrition, texture, storage). I also give them a small sample to try with the staff. This is often all it takes, but I only approach restaurants that I think really get the concept of quality ingredients. I have approached 15 restaurants and successfully marketed to 12, now my "regulars". My higher prices were the main factor for the 3 who did not take my shiitakes.

"You really want to make the life of the restaurant person as easy as possible. If you take on a restaurant account, you have to make sure, as best you can, that you have an assured supply of high quality, fresh shiitakes and deliver when they need them. I now know the menu-planning habits, best buying days and best delivery times for all my accounts and try to reasonably fit into that the best I can. Some accounts have come right out and said to me that they know they can get log-grown shiitakes cheaper elsewhere but they like my assured supply and commitment to quality. With a few accounts I feel like part of their 'family' now. "

- Steve Sierigk, Hawk Meadow Farm

Farmer's market mushroom display. (Steve & Julie Rockcastle, Green Heron Growers)

prefer smaller ones. Consumers have varying preferences.

At Farmers Markets

- Offer free samples, recipes or pamphlets to help customers realize how tasty and fun mushrooms can be.
- Start with smaller price tags. For example $4 per quarter pound versus $16 per pound.
- Selling by the basket works well. Baskets can be expensive, but $5, $10, or $20 per basket simplifies the purchasing process for consumers.
- Thursdays and Fridays are days of high demand, coming into the weekend, when people are more festive with their food.
- Most growers do not separate caps from stems. Some experimented with selling "caps-only" mushrooms for a premium price.
- Consider rewarding your regular buyers.

RESEARCH: *Consumer Preferences*

A survey was conducted at the Trumansburg Farmer's Markey aimed at exploring the perceptions and behaviors of consumers who purchase mushrooms. Based on this survey, researchers determined the following:

- Consumers indicated that they were more likely to purchase fresh mushrooms, rather than dried.
- Consumers indicated they that would be more likely to purchase and pay more for a food with greater heath or medical benefits (functional food)
- Consumers indicated they had the most confidence in a health claim made in the scientific literature, followed by a medical professional. This means that if a farmer in a farmer's market is advertising the health benefits of their products, then they should be sure to include the source of their claims for improved authority and trustworthiness.

(Adapted from thesis research by B. Sobel (2013) of Cornell University)

EXPERT TIPS: *Selling Inoculated Logs*

"I have been selling some logs during the autumn for $35 each. However, I think that selling them in May as "ready-to-fruit logs" would result in a lot more sales. I have had a lot of people asking me why I was selling them this fall and they seem very concerned about caring for them over the winter. So, I would suggest selling logs in the spring. As far as a price goes, you can do some Internet research and find that logs are selling for $30 to $40-plus and they are 12 to 18 inches long on the internet.

- Matt Anderson,
Tyrrel Mushroom Farm

"I encourage people to get multiples as they would be more likely to look after them than if it were just one. New this year I started to advertise ... the purchase of your own mini shiitake yard ... I only had enough logs to sell 3 of these. This included 14 of these smaller logs, where you could force 2 each week for a 7-week cycle to get yourself a steady supply of shiitakes. I sold these for $225 and it came with a 30-minute consult. I easily sold 3 sets like this and this was a great way to go. I could probably increase the price here, too ,but there is a certain efficiency in dealing all with one person and building a long term relationship as these folks will look to recharge logs soon enough. They quickly become the envy of their neighborhood and people will look to get their own."

- Steve Sierigk, Hawk Meadow Farm

At Restaurants

- Talk with local chefs to see if they might be interested in your product. It's nice if you have some information to leave them; be sure that your contact information is clearly visible.
- Ask if they would like you to provide sample products.
- If certain restaurants are willing to buy particularly large quantities, consider offering a bulk discount.

At Grocery Stores

- Stores that put emphasis on buying locally or eating healthy foods are good choices for your product. At the right venue, your buyers will be pleased to sell a great product that makes their store look good to consumers.

Selling Inoculated Logs

In addition to selling shiitake mushrooms, growers may also want to consider selling inoculated shiitake logs to mushroom hobbyists. To entice potential buyers, we recommend selling "ready-to-fruit" logs; the buyer can go home, soak it, and get mushrooms a week later. We also recommend that these logs be smaller than the ones used in a commercial operation - anywhere between 12 to 28 inches is normal.

What will it take to sell mushrooms from 100 logs for 1 year

10	$25	Paper Bags Labels Baskets Paper Bags
Hours of Labor	USD	

*Values based on data collected from 17 farmers starting a shiitake operation

Enterprise Viability

Forest owners and farmers interested in producing shiitake mushrooms as a new enterprise should develop an Enterprise Assessment to analyze opportunities, examine competition, clarify resources and project expenses needed prior to making a firm commitment to proceed with the new venture.

An Enterprise Assessment can assist us to project economic impacts from specific management and production changes, in examining alternative markets, in developing value-added products and in analyzing the feasibility of adding shiitakes to an overall farm business. An Enterprise Assessment examines revenue and expenses to be budgeted only in relation to one specific enterprise, rather than analyzing the entire farm or business operation's income and expenses. A broader assessment can compare the income and expenses for multiple activities involved in diversifying your operation.

In the following pages, we've included two enterprise assessments. The first is actual records from a large commercial shiitake enterprise (Green Heron Growers). The second is an estimate of what expenses and profits a farmer could expect beginning a smaller shiitake enterprise; the values in this estimate were based on data collected from 14 beginning shiitake farmers in the Northeast. Lastly, we've included a blank spreadsheet to help guide you in completing your own Enterprise Assessment.

Scenario One: Large Commercial Production

Between 400 and 800 logs inoculated per year with over 2,000 logs in rotation

The following data was gathered by one thriving shiitake enterprise, Green Heron Growers. It is intended to show how much a well-organized and dedicated grower can expect to make, if working with a large number of logs.

BASIC PRODUCTION INFORMATION

	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*
Logs Inoculated	800	500	600	400	400	468
Logs Fruited	0	660	1100	1400	1100	1389
Pounds Harvested	0	150	260	662	685	696
Pounds Per Log *(average)*	0	0.23	0.24	0.47	0.62	0.50

EXPENSES

	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*
Start-up	$1,000	$1,203	$220	$220	$200	$200
Equipment & Fuel	$82	$85	$130	$82	$77	$39
Labor	$1,340	$782	$335	$500	$810	$795
Supplies: Inoculating	$1,333	$603	$480	$664	$665	$652
Supplies: Other	$484	$281	$447	$497	$237	$942
Total	$4,239	$2,954	$1,612	$1,963	$1,989	$2,628

Labor cost projections were made assuming a hourly wage of $10 was paid to everyone working on the project

FARMER LABOR

	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*
Tree/Log Cutting						
Inoculation	$1,500	$980	$820	$1,050	$530	$800
Shocking/Forcing		$600	$750	$750	$750	$750
Harvesting & Processing		$750	$850	$750	$750	$750
Value-Added				$500	$500	$500
Marketing & Sales				$600	$500	$400
Total	$1,500	$2,330	$2,420	$3,650	$3,030	$3,200

SALES

	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*
Sales of Fresh & Value-added Products	$-	$987	$3,109	$6,969	$7,069	$7,382

NET PROFITS AND LOSSES

	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 6*
Total Income	$0	$987	$3,109	$6,969	$7,069	$7,382
Total Expenses Without Labor	$4,239	$2,954	$1,612	$1,963	$1,989	$2,628
Net Profit Without Labor Costs	-$4,239	-$1,967	$1,497	$5,006	$5,080	$4,754
Profit (labor subtracted)	-$5,739	-$4,297	-$923	$1,356	$2,050	$1,554

The first profits were generated the third year

EXPERT TIPS: *Putting Profits into Prospective*

Don't be scared off as you look at the slow and expensive start our shiitake operation had. We started out using red maple logs the first two years and did not have great results. Because you never know how the logs will produce till the second year, we went ahead with red maple again the second year, because that was what we had on our land. Best thing about this was the reduction of this low quality tree in our woodlot! On top of that, we inoculated with CW, WR and WW strains the first year and mostly WW the second year because it was recommended by the supplier for red maple. We were not impressed. Harvests seemed good to us as newbie's, but when our Cornell friends said to expect close to a pound a year/log we know something needed to change. The third year got oak logs from nearby state lands and used mostly WR & CW. Since then we're begun harvesting sugar maple and beech from our land one year and then oak from off site the next year.

Our high start-up expenses also make this enterprise not look all that "viable". The perfect location for our shiitake yard is very far from our house. It was the only hemlock grove that wasn't in a swamp, so we had to make it accessible by building a section of gravel road. The need for water also required investments. Labor for inoculating was another high cost, but we've gotten better at creating workshops and volunteer opportunities to get that done.

So we've learned a lot and enjoy our shiitake experience immensely. Year 7 our income rose to $9,000 and costs remained much the same. We wouldn't want to stop now!

- Steve and Julie Rockcastle, Green Heron Farm

(Brad and Terri Jamison, Warrensburg, NY)

Scenario Two: Small 100-Log Operation

100 Logs Inoculated each year for 5 years

In 2011, 21 aspiring shiitake mushroom growers inoculated 100 logs with shiitake spawn. Over the course of the next two years, growers kept detailed records of their labor, expenses, production and sales. Using their data, we've estimated the expenses and income one could expect during the first five years of a small shiitake commercial shiitake production operation.

The assumptions used to generate each analysis are listed to the left of each table. Keep in mind that these values are averages (means) and that there was substantial variation between growers. Where appropriate, we've included a chart illustrating the range.

Product and Market Information

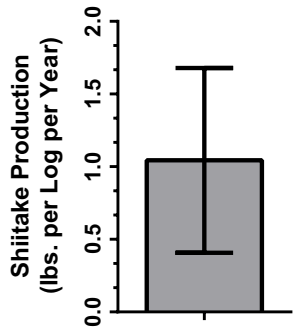
This estimate assumes that growers inoculate 100 logs per year for five years. Beginning farmers in the study produced approximately 1 pound of mushrooms from each log during the study's second year. Farmers sold their mushrooms for about $12 per pound (on average), predominately to restaurants and at farmers markets. Through these sales, they were able to generate roughly $1,237 during the second year; if these trends continue, they could expect to generate nearly $5000 per year during the fifth year of the operation when 371 logs would be actively fruited.

PRODUCTION & MARKET INFORMATION

	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*
Logs Inoculated	100	100	100	100	100
Logs in Laying Yard	100	197[1]	291[1]	382[1]	471[1]
Logs Fruited	0	97	191	282	371
Shiitake Production (total lbs.)	0	101	199	294	386
Shiitake Production (average lbs. per log per year)		1.04	1.04[2]	1.04[2]	1.04[2]
Price per pound (average)		$12.26	$12.26	$12.26	$12.26
Total Income	$0.00	$1,237	$2,436	$3,600	$4,729

[1] Value assumes that 3% of logs are culled each year as a result of bark, insect and/or competitive fungal damage.

[2] Assumes that logs produce, on average, the same amount of mushrooms each year, over their lifetime. In reality, production will peak during the third year and be highly variable depending on a wide range of factors (see "EXPERT TIPS: What yields to expect and how to improve yields" on page 37).



The weight of mushrooms produced by a single log varied substantially among growers depending on the species of tree they used, timing of inoculation and general management scheme. There are a variety of explanations. In this study, we observed growers who spent more time working on their operation had better-producing logs, likely because they took better care of the logs. In addition, growers that used oak and maple realized higher yields than growers using other tree species. Lastly, logs inoculated soon after the trees were felled yielded more mushrooms. For more information about yield per log, see Expert Tip on page 37.

Annual Expenses

There are many ways to calculate operation expenses. Below we've listed the items most commonly purchased, and the average amount participants spent on each item. We also listed the average amount that participants spent on other durable and non-durable expenses during years one and two.

For certain durable items, such as a chainsaw, we've also assumed that these items will need to be replaced every three to five years (depending on the item). To account for this upcoming cost, we've amortized the cost of the items over the years preceding their purchase. In other words, money is put aside each year to save up the future purchase of big-ticket items based on how long the item is expected to last.

Using these assumptions, we find that the cost to start a small shiitake operation is approximately $1,000. Keep in mind that for many landowners who already own items like a chainsaw, angle grinder and shade cloth, the up-front costs will be much lower. Ongoing cost total roughly $500 per year.

ANNUAL EXPENSES

	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*
			Tree-Cutting Supplies		
Chainsaw*	$363.33	$72.67	$72.67	$72.67	$72.67
Chainsaw Chain*	$35.75	$7.15	$7.15	$7.15	$7.15
Chainsaw Chain Sharpening	$36.67	$7.33	$7.33	$7.33	$7.33
			Inoculation Supplies		
Drill Bit**	$29.65	$9.88	$9.88	$9.88	$9.88
Inoculation tool**	$32.64	$10.88	$10.88	$10.88	$10.88
Wax	$33.23	$33.23	$33.23	$33.23	$33.23
Angle Grinder Adaptor*	$36.14	$7.23	$7.23	$7.23	$7.23
Spawn	$110.00	$110.00	$110.00	$110.00	$110.00
Wax Applicators	$7.67	$7.67	$7.67	$7.67	$7.67
Generator Gasoline	$9.67	$9.67	$9.67	$9.67	$9.67
Food	$15.41	$15.41	$15.41	$15.41	$15.41
			Harvesting, Packaging, Sales		
Shade Cloth *	$123.69	$24.74	$24.74	$24.74	$24.74
Plastic & Paper Bags	$20.78	$20.78	$20.78	$20.78	$20.78
Gasoline	$50.74	$50.74	$50.74	$50.74	$50.74
			Other Expenses		
Other Non-Durable	$71.00	$67.00	$67.00	$67.00	$67.00
Other Durable	$65.00	$36.00	$36.00	$36.00	$36.00

* Items are replaced every 5 years. Cost of repurchase amortized over 5 years.

** Items are replaced every 3 years. Cost of repurchase amortized over 3 years.

Other Non-Durable Expenses

Includes business cards, chainsaw repairs, flagging tapes, labels, organic certification fee, propane, shipping expenses, spread ingredients, tent and tractor Rentals

Other Durable Expenses

Includes building materials, extension cords, baskets, generators, gravel hoses, safety equipment, scales, signs, stoves, tables, tents, water tanks, and wax pots

Labor

Participants in the research project recorded how much time they spent performing various activities related to their shiitake mushroom operation. We've compiled the data in the table below. In order to project beyond the two-year span of this project, we've also made the assumption that, for certain activities like forcing logs, and harvesting processing and selling mushrooms, the amount of time required will increase proportionally to the number of logs in rotation.

During the first year, expect to spend about 60 hours on shiitake mushroom production related activities. The number of hours necessary will increase as the number of logs handled increases.

LABOR (HOURS)

	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*
Cutting/Felling Trees	12.1	12.1	12.1	12.1	12.1
Inoculating Logs	30.7	30.7	30.7	30.7	30.7
Laying Yard Maintenance	6.2	4.0	4.0	4.0	4.0
Forcing Logs	0.0	7.5	14.7	18.1	25.0
Harvesting Shiitake	0.0	7.8	15.4	19.0	26.2
Processing Shiitake	0.0	3.8	7.5	9.2	12.8
Selling Mushrooms	0.0	9.7	19.1	23.5	32.5
Other	8.4	8.4	8.4	8.4	8.4
Total Hours	**57.4**	**84.0**	**111.9**	**125.0**	**151.6**

Profits and Losses

Using the data from the "Annual Expenses" and "Production and Market Information" we can calculate expected profits/losses for each year of the shiitake operation. In the table below, "Annual Net Profit and Loss" is the profit/loss from a single year. "Net Profit or Loss to Date" is the sum of the profits and losses from the preceding years; in other words, it is the total amount generated or loss during the enterprise's duration.

Based on the data from the 13 farmers in this project, and using the assumption described above, one small shiitake mushroom operation could be expected to generate $9,000 in over five years. It would take three years to recoup the operation's startup costs.

PROFITS AND LOSSES

	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*
Total Enterprise Expenses	$1,041	$490	$490	$490	$490
Annual Income	$0	$1,237	$2,436	$3,600	$4,729
Annual Net Profit or Loss	$1,041	$746	$1,946	$3,110	$4,239
Net Profit or Loss to Date	$1,041	$295	$1,651	$4,761	$9,000

Create your own Enterprise Assessment

	Year 1	Year 2	Year 3	Year 4	Year 5
Production Information					
Number of Logs Inoculated					
Number of Logs Fruited					
Expected Shiitake Production Per Log					
Cash Receipts					
Pounds of Shiitakes sold (retail)					
Pounds of Shiitakes sold (wholesale)					
Avg. price per pound (retail)					
Avg. price per ounce (wholesale)					
Total Enterprise Receipts					
Enterprise Expenses					
Direct Enterprise Expenses					
Mushroom Spawn					
2 Brass Inoculators					
Wax					
Misc, supplies					
Grinder (1) and Bits (2)					
Fuel					
Marketing, Ads					
Processing, Packaging					
Repairs, Maintenance					
Sprinkler and Hoses					
General Supplies					
Refrigeration					
Total Direct Expenses					
Depreciation or Capital Replacement					
Insurance					
Interest on loan payments					
Principal on loan payments					
Rents, Rentals, Leases					
Utilities					
Other: _____					
Total Fixed Expenses					
TOTAL ENTERPRISE EXPENSES					
NET PROFIT OR LOSS					

Direct Enterprise Expenses are ONLY income and expenses explicitly for THIS enterprise.

To include what you will have to pay whether you have this enterprise or not - as a share for this enterprise - put them under Fixed/Overhead Expenses.

Have More Questions?

Join the Mushroom Listserv:

Since 2010, over 100 growers and mushroom enthusiasts have been involved in a Northeast-based mushroom listserv. Much of the material for this manual was drawn from valuable discussions that took place over the listserv. We encourage you to join this ongoing listserv following these directions.

To get connected to the Mushroom listserv:

- Send an e-mail to listserv@list.uvm.edu
- In the Subject line type: mushrooms
- In the body of the e-mail, type:
  subscribe mushrooms your_email_address
  For example: ***subscribe mushrooms ane.doe@gmail.com***
- If you receive a confirmation message from LISTSERV asking you to verify your identity, just follow the instructions in the message.

Join the Northeast Forest Growers Network

The Northeast Forest Mushroom Growers Network website is the official online meeting place for the NE SARE-funded project, Cultivation of Shiitake Mushrooms as an Agroforestry Crop for New England. The aim is to provide information about the cultivation of specialty forest mushrooms and foster communication and cooperation among amateur and professional mushroom growers.

On the website, you can learn about upcoming events and mushroom inoculation classes, download the latest factsheets and publications, watch video demonstrations of inoculation techniques, register your farm in your mushroom grower directory and much more. **Check it out at *http://blogs.cornell.edu/mushrooms/.***

The Latest Research into Shiitake Mushrooms

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INOCULATION
SPAWN RUN
FORCING FRUITING
HARVEST
PROCESSING
SALES

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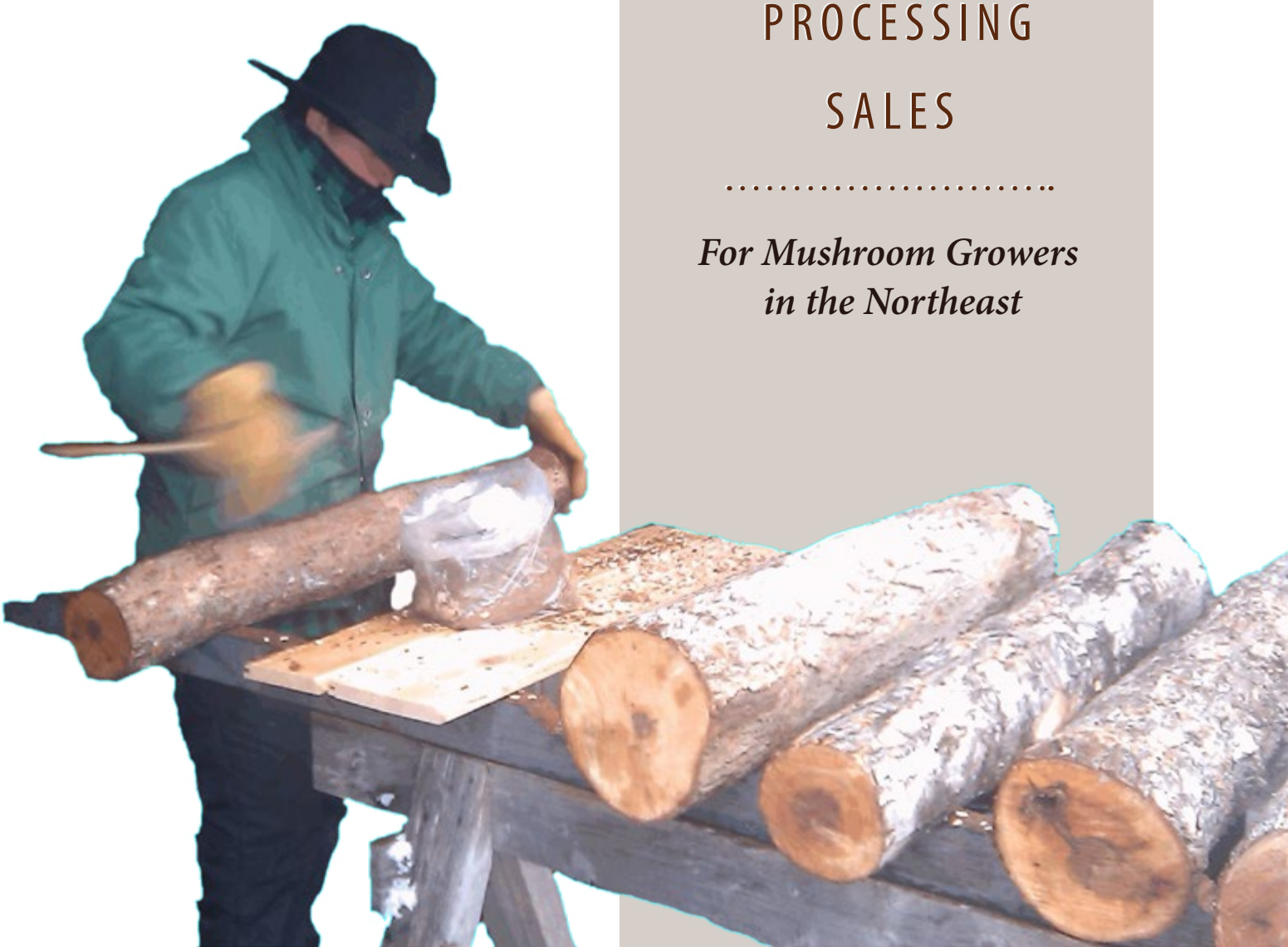
For Mushroom Growers in the Northeast