

Shiitake Mushrooms

LOG BASED & FOREST SHIITAKE MUSHROOM CULTIVATION IN NEW ENGLAND

Cultivation of shiitake mushrooms is a fairly simply process. This guide will help you plan for an effective cultivation experience and give you some insight before you have the logs out and ready to grow mushrooms. Keep in mind that this process is slightly different for each grower and will benefit from personal adjustments as you become a more accomplished grower. Here is how we do it and some advice we learned along the way.

BACKGROUND

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.

OVERVIEW

Forest cultivation of shiitake mushrooms can be a profitable method of diversifying home income by utilizing low-value forestry by-products while creating opportunities for timber stand improvement. Production involves inoculating fresh cut hardwood logs by placing *spawn* (cultured fungus) into holes drilled in the log. Logs are then incubated in a *laying yard* under forest shade for about 1 year before *fruiting* (mushrooms) begins. The log will continue to fruit biannually for 3-4 years generating 1/2 pound or more mushrooms at each flush. These log grown shiitake mushrooms sell for \$12-\$16 per pound throughout New England.

MORE INFORMATION

For more information about the shiitake mushroom production and processing, visit the Northern Forest Mushroom Growers Network at <http://mushrooms.cals.cornell.edu/>.



© Nicholas Laskovski—Dana Forest Farm

ABOUT SHIITAKE (*LENTINULA EDODES*)

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

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

Odor/flavor: robust, earthy

Does it grow wild in the United States: No



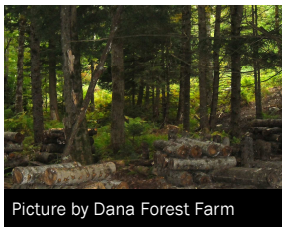
CHOOSING A LAYING YARD

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.

IMPORTANT FACTOR TO CONSIDER

Year-round shade (75-100%) 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. A deciduous canopy will suffice but it will be necessary to protect the logs with 80% shade cloth or pine boughs during the winter.



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.

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 wetted to maintain moisture levels, logs may be submerged under water or dampened under a sprinkler. 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 - 45 % moisture content and should not drop below 25%. Ideally the water should come from a well or stream (chlorinated public water will harm the mycelium), cool, and clean.



Other Aspects

Other important aspects of the laying yard include slope, microclimate, and accessibility. The slope and microclimate of the laying yard will affect how you lay the logs. For example, if it is a sight with lots of exposure to wind, one may choose to lay logs closer together to maintain log moisture. 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. Windbreaks (to keep logs from drying out)



**ALWAYS
REMEMBER THAT
OPERATING A
CHAINSAW CAN BE
DANGEROUS. TAKE
PROPER
PRECAUTIONS!**

The Game of Logging (GOL) is widely acknowledged as the premier timber harvesting 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>



Optimal Log Size

Picture by Allen Matthews, UVM

LOGS & BOLTS

Picture by Allen Matthews, UVM

WHAT TREE SPECIES TO USE

Oak is often considered the species of choice for shiitake production in North America. Research at the Cornell University has shown that red and white oak performed about the same as substrates for shiitake. 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 might be less than optimal for mushroom production.

A number of other species have been shown to be as productive as oak. These include: American beech (*Fagus grandifolia*), Sugar maple (*Acer saccharum*), American hornbeam (*Carpinus caroliniana*) and Hophornbeam (*Ostrya virginiana*). We have no experience with Chestnut, Ash, Alder, Elm, and Tupelo. Although we don't know how well these species will perform, we encourage you to try them out if the trees are available. Don't use the wood from any evergreen tree (pine, spruce, hemlock, etc.) We also don't recommend using birch or aspen.

BUYING BOLTS

You may also consider buying pre-cut lengths (cost \$1.00 - \$2.00 / bolt). 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, 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.

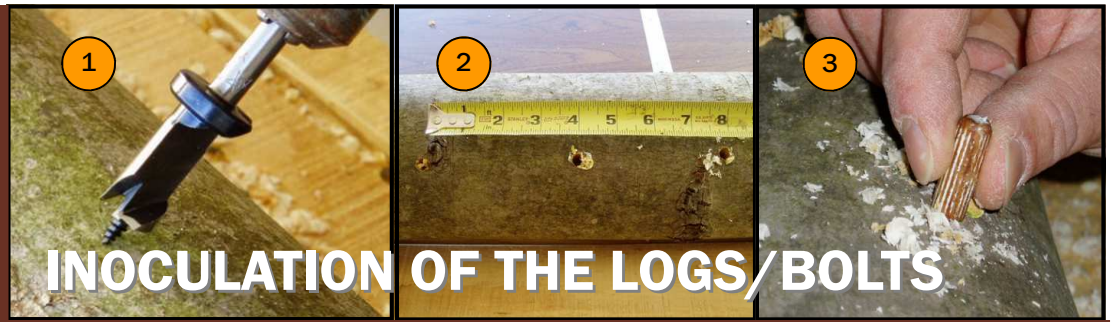
WHEN TO CUT THE TREE DOWN

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 chainsaw.

Only living trees should be cut down. It is important to have fresh logs for inoculation because they have a high moisture content, and little or no competing wild fungi, which are two important factors for successful mushroom cultivation. If you are cutting your own trees, it is best done at least a couple of weeks before bud-swell in the late winter or early spring. This is also the time when the bark is tightest around the trunk and will prevent early bark loss later on. An intact bark is a very important component of the log in order for it to retain moisture and block pathogens from entering the log.

OPTIMAL SIZE OF LOGS/BOLTS

Logs should typically be 4-6 inches in diameter. Larger logs can be used but they are obviously more difficult to manage. This diameter range was chosen 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. 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.



WHEN TO INOCULATE...

We recommend that the logs be stored for two to four weeks before being inoculated. Regardless of how long you wait to inoculate, do not store bolts in the sun. If a log is cut and left to sit for an extended period of time before inoculation, other species of fungi can invade the log or the log can dry out.

WHAT TYPE OF SPAWN TO USE

Bolts can be inoculated with sawdust spawn or plug spawn. There are advantages and disadvantages to each. Plug spawn is very simple to use—the only tool needed is a hammer or mallet. The drawbacks are that plug spawn is slightly more expensive per log than sawdust spawn, and the mycelium may take a while to migrate out from the plug spawn. Sawdust spawn is slightly cheaper than plug spawn, but it requires a special tool, either purchased or home made, to insert the sawdust in 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. Other than that, the methods are the same between inoculating logs with plug spawn and with sawdust spawn.

DRILL OR ANGLE GRINDER?

Outfitting an angle grinder with a drill bit is another method of drilling holes into the log. (This requires an adaptor for the angle grinder.) 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.

THE DOWEL INOCULATION METHOD

We recommend reviewing the video at <http://mushrooms.cals.cornell.edu/cultivation.htm> for step by step directions regarding drilling and inoculation. Drill holes, 5/16" diameter, 1" deep, every 4 inches along the log. Rotate log and repeat. To create a diamond pattern, shift the drill bit 2" down along the guide for every other row. Typically 1 row of holes is drilled for every inch of log diameter. Place a plug (dowel) spawn in each drilled hole and hammer it into the log. Each plug should lie just below flush with the log surface.

THE SAWDUST INOCULATION METHOD

The first step in inoculation is drilling holes into the bolt. For sawdust-based inoculation, use a 7/16" drill bit size and drill to a depth of 1.25". We recommend a drill bit with a built in drill stop; it is better than the adjustable drill stop you purchase in an ordinary hardware store. More holes are not detrimental and, in fact, are likely to speed up colonization of the log.

After the holes are drilled, it is time to place the spawn in the holes, bringing the shiitake mycelium in contact with its new food source (substrate), the log. Stab the inoculation tool into the spawn and pound it once or twice. To inject the spawn, place the tool over the hole and depress the plunger at the top to compact the spawn into the hole; the hole should be full so that the spawn is level with or just below the surface of the log. Repeat this process for all holes.



Sawdust Inoculation
Picture by Allen Matthews, UVM



Picture by Allen Matthews, UVM



Wax Pot
Picture by Ken Mudge, Cornell

Waxing the holes helps seal in moisture so that the spawn does not dry out. By sealing off the holes, the chance of contamination by competing fungi species is reduced. During this step each hole is completely sealed using food grade 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 (wisps of smoke).

You can apply the wax in a number of different ways. Foam paint brushes (\$0.50 - \$0.80 / brush) are very effective and many people already own a foam paint brush. One inch brushes work best. These can be reused many times (until the brush comes off of the wooden handle). Cotton daubers (\$30.00 / 144 pc = \$0.21 / 1pc) are cheaper than foam paint brushes. These small cotton balls on the end of a wire handle are available from select mushroom product suppliers. They can be reused and are very effective.

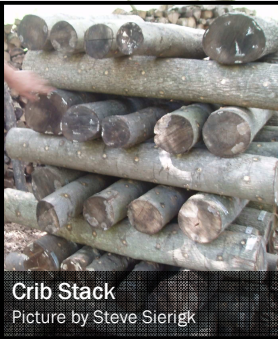
To apply the wax, use the chosen applicator to transfer the hot wax onto each hole in the log. Care should be taken to seal the hole. One dip of the applicator should complete a few holes.

WAXING THE ENDS

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 choose to skip this step. 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 prevents competitive fungi from gaining a foothold. However, wax also is 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.

STACKING LOGS

Picture by Green Heron Growers



Crib Stack
Picture by Steve Sierigk



High A Frame
Picture by Green Heron Growers



Japanese Hillside
Picture by Ken Mudge, Cornell

CRIB STACK (RICK STACK)

Crib stacks are simple and quick to make. First, four to five logs are laid down on a flat surface, then four to five logs are placed on top of them in the opposite direction; the pattern is continued for about five levels.

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.

HIGH A-FRAME

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 easily visible, and picking is easy as there is maximum access to each log. Because the log is vertical, slug damage to mushrooms may be less than when logs are fruiting closer to the ground.

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.

JAPANESE HILLSIDE METHOD

This stacking method is more complex 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 raised off the ground, potentially reducing slug damage. For more information on this stacking method see "Our Cultivation Guides" featured on the Northern Mushroom Growers Website at <http://mushrooms.cals.cornell.edu/>





Picture by Dana Forest Farm

FRUITING SHIITAKES

In a natural production model, growers do not do anything to the mushroom logs to make them fruit. Logs are left to fruit naturally, fruiting either when there is heavy rainfall or when a temperature change encourages fruiting. In a forced production model, growers control when logs fruit. Logs may sometimes also fruit naturally. (In fact, heavy rain can knock the production schedule way out of whack) but most harvests are induced according to a preplanned log rotation schedule. Because yields can be predicted and kept relatively constant in this model, it has greater retail potential.

SHOCKING

Shocking, or forcing, is the process used to force mycelium into fruiting body (mushroom) production. Soaking logs in cold water for an extended period of time will induce fruiting. Place the logs in the coldest water you have available — a 100 gallon cattle trough or big tub works best. Because temperature adjustment is not practical, we recommend a fast moving stream or tank kept out of the sun. Leave the logs submerged in the water for 12 to 24 hours. Then remove the logs from the water and stack them in an A-frame (conducive to the upcoming harvest). In 3 – 5 days, the log will begin pinning, or sending up the beginnings of mushrooms. These will grow and develop into full-sized shiitake mushrooms.

HOW OFTEN TO SHOCK

After fruiting, logs need to be rested for 6 - 8 weeks before being forced again. The more often the logs are shocked, the shorter their lifetime is likely to be. We recommend only shocking once during first production year, then twice during the second and third year.

Logs should be stacked in the laying yard so they are easily identified in order to establish a schedule for shocking and harvesting. This plan should take into account the number of times each log will be forced a season, when logs will be forced, how logs will move through the laying yard, when mushrooms are needed, when the plan predicts mushrooms will be available, and when logs will be retired at the end of their lifetime.

WHEN AND HOW TO HARVEST

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 are usually ready 7 - 10 days after shocking although colder temperatures will slow their growth. Using a knife is quick, easy, and ensures a clean cut on the stem. It also does not rip or damage any bark.

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 0.25-0.5 lb of mushrooms per log or higher per flush, with the goal of doing two shockings per season.



Logs Fruiting

Picture by Dana Forest Farm

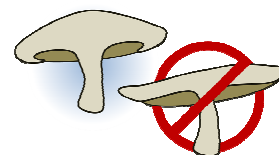
HARVESTING & PROCESSING

Picture by Green Heron Growers

Shiitake mushrooms can be processed in a variety of ways. The fresh mushrooms retain the best flavor and texture however, they can only be stored for a short period of time. By processing the mushrooms, either through drying, bottling, canning, pickling and freezing, you can make good use of extra mushrooms to extend your year-round sales.

HARVESTING

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. Harvest mushroom with a sharp knife or by twisting the stem so it breaks free. 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.



Picture by Green Heron Growers

STORING FRESH SHIITAKE 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 or 5°C), dry, and dark place. Do not seal them in an airtight container.

FREEZING SHIITAKE MUSHROOMS

Mushrooms need to be treated to stop maturation before freezing, usually by steaming. 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 5 minutes, buttons or quarters 3.5 minutes and slices 3 minutes. Cool promptly, drain and package, leaving 1/2-inch headspace. Place small packages in the freezer for fast cooling.

DRYING SHIITAKE MUSHROOMS

Drying can preserve large quantities of mushrooms up to a year. The dried mushroom has a moisture content of approximately 13% and weighs about 1/7 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 down. Avoid allowing the mushrooms to touch each other. You can also slice them vertically (tangentially) into approx. 1/4 inch pieces. They dry faster, rehydrate faster, and look more appealing when dried.

When oven / thermal drying, Arrange the mushrooms on shelves with the gills facing upwards. The drying chamber should be maintained at 40-50°C for 24 hours. The mushrooms should then be cooled for one hour before being stored long-term. If drying the mushrooms in your oven, set the temperature to 200°F (95°C) and keep the door ajar. To sundry, Spread the shiitake on shelves so that the gills are directly exposed to sunlight. You can also string up them using thread or fishing line and then hang and dry them in a breezy, dry spot. Length of time required will vary depending on the weather conditions. Individual mushrooms dry at different rates depending on their exposure and size.



Stir-frying shiitakes

Picture by Dana Forest Farm



Sun drying shiitake mushrooms

Picture by Dana Forest Farm



FARM OPERATION

SAMPLE FARM OPERATION

Year	Logs at Start of Year	No. of Fruiting Logs	Lbs. per Log	Lbs. of Shiitake	Retail @ \$15/lb.	Wholesale @ \$8/lb.
1	130	0	0	0	\$0.00	\$0.00
2	257	127	1.5	190.5	\$2,857.50	\$1,524.00
3	381	251	2	502	\$7,530.00	\$4,016.00
4	503	373	1	373	\$5,595.00	\$2,984.00

SAMPLE BUDGET: INCOME VS EXPENSE

Year	1	2	3	4
Retail @ \$15/lb	\$0.00	\$1,905.00	\$7,530.00	\$8,392.50
Wholesale @ \$8/lb	\$0.00	\$1,016.00	\$4,016.00	\$4,476.00
Hypothetical Sales	\$0.00	\$1,460.50	\$5,773.00	\$6,434.25
Supplies Cost	\$978.00	\$494.00	\$674.00	\$844.00
Hours of Labor	40	104	110	144
Cost of Labor (@ \$12/hr)	\$480.00	\$1,248.00	\$1,320.00	\$1,728.00
Total Expenses	\$1,458.00	\$1,742.00	\$1,994.00	\$2,572.00
Net Profit	-\$1,458.00	-\$281.50	\$3,779.00	\$3,862.25

EXAMPLE OF SHIITAKE PRICES

Location	Wholesale		Retail Sales	
	Organic price per lb	Conventional price per lb.	Organic Price per lb	Conventional price per lb.
Boston	9.28	5.42	16.00	12.00
NY, NY	7.14	5.67	17.50	13.00

DEVELOP A MARKETING PLAN

- Identify market area
- Identify target markets
- Identify competition (may be your best partner)
- Decide on marketing tools (logo, newsletter, website, signage, discounts, etc.)
- Determine success (# of customers, new and repeat sales, income, etc. .)



MATERIALS COSTS AND CHECKLIST

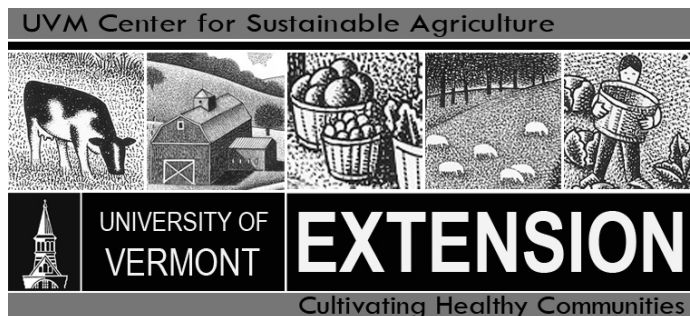
- ☒ Access to water for force fruiting.
- ☒ A cultivation area with modest shade and protection from wind.
- ☒ Hardwood logs cut from healthy saplings or pole-size trees, or from tops of larger trees.
- ☒ Spawn and plunging tool: (Spawn and the following supplies can be purchased from professional supplier.)
- ☒ Cheese wax: For sealing spawn.
- ☒ Daubers: For applying cheese wax.
- ☒ Very high speed drill, available from professional suppliers. If you only purchase one piece of equipment, it should be the highest speed drill you can find.
- ☒ Appropriate drill bits.

**ELECTRONIC
BALANCE:** (1000g
max, 1g resolution):
\$40-\$60

ELECTRIC DRILL
\$40-\$60 for a low-end
model

ANGLE GRINDER
\$60 for a low-end
model

	COMPANIES			
	Field & Forest	Fungi Perfecti	Mushroom People	Mycosource
Sawdust Spawn	\$18 / 2 lb. \$23 / 5.5 lb. \$21 / 5.5 lb. (7-10 bags) \$15.75 / 5.5 lbs. (11-49 bags)	\$19 / 5 lb. \$17.10 / 5 lb. (10-19 bags)	\$19 / kg \$17 / kg (10-19 bags) \$12 / kg (20+ bags)	\$30 / 2.5 kg \$25 / 2.5 kg (5+ bags)
Inoculator*	\$35 (palm style) \$33 (thumb style)	\$34.95 (palm style)	\$27 (palm style)	\$27 (thumb style)
Drill bit - 7/16"	\$9.50	--	\$9.50	\$15
Depth stop - 7/16"	\$1.75	--	\$2.50	--
Adaptor (for angle grinder)	\$35	--	--	\$40
Drill bit - 7/16" w/ depth stop (for angle grinder)	\$13	--	--	\$20
Adapted angle grinder	\$125	--	--	--
Cheese Wax	\$8.50 / 2.5 lb \$15 / 5 lb \$137.50 / 55 lb	\$4.95 / 1 lb \$34.95 / 10 lb	\$3.20 / 1 lb	--
Wax Applicators	\$1 / 4 \$30 / 144	--	\$0.30	--



UVM Extension helps individuals and communities put research-based knowledge to work.

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the United States Department of Agriculture. University of Vermont Extension, Burlington, Vermont.

University of Vermont Extension, and U.S. Department of Agriculture, cooperating, offer education and employment to everyone without regard to race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, and marital or familial status.



Cornell University
College of Agriculture
and Life Sciences

Cornell University provides equal program, employment and education opportunities.

Contributors to this pamphlet associated with the University of Vermont include Allen Matthews, Bridgett Jamison, Nick Laskovski, and Ben Waterman. Contributors from Cornell University include Ken Mudge, Alyssa De Villiers and Rachel Brinkman.