Mushroom cultivation in Thailand

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Peace Corps
INFORMATION COLLECTION & EXCHANGE
Reprint Series No. R - 63

Printed By:
PEACE CORPS
Information Collection and Exchange
March 1987

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This handbook was written in an endeavor to help volunteers of all backgrounds better understand mushroom culture in Thailand. We attempted to cover the topics we felt were of greatest importance to volunteers wanting to extend mushroom cultivation to villagers. We realize that this handbook is incomplete in some areas and, therefore, we encourage anyone who uses this handbook to make written comments, both pro and con, to Peace Corps/Thailand, in c/o the Ag/RD Office.

January, 1987

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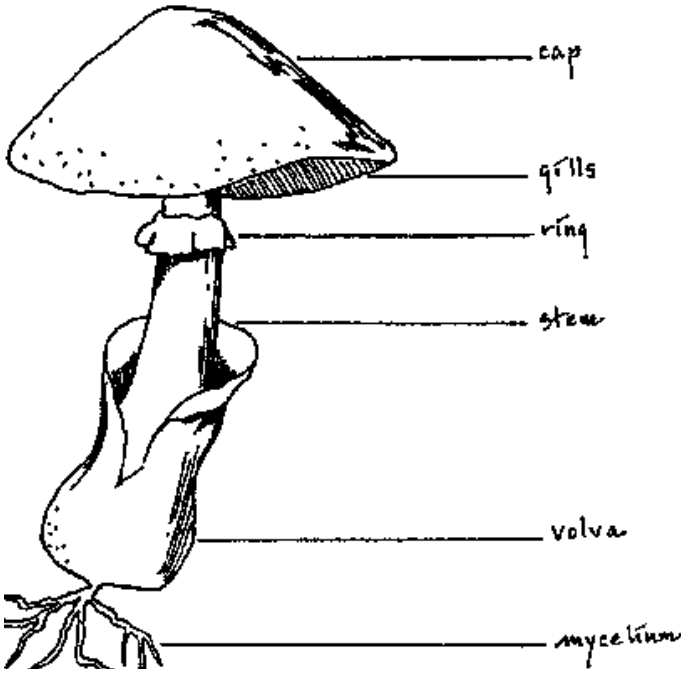
Figure 1: Parts of a Mushroom



1. Introduction to mushroom cultivation in Thailand

Mushrooms, a fungus in the class Basidiomycetes, have a high nutritional value and are thus very beneficial to humans. Mushrooms contain more essential minerals than red meat, are low in fats and are a good source of protein. Medical research has also shown that mushrooms contain eritadenine, a substance that helps prevent fat build-up in blood vessels.

Many types of mushrooms are grown and collected in Thailand for home consumption and sale in local markets. The mushroom varieties most commonly grown on a commercial scale in Thailand are:

1. Straw mushrooms (Volvariella volvacea)
2. Angel mushrooms (Pleurotus sarjov-coju)
3. Oyster mushrooms (Pleurotus ostreatus)
4. Abalone mushrooms (Pleurotus cystidiosus)
5. Wood ear mushrooms (Auricularia auricula)

In addition to these commercially grown varieties, many types of native mushrooms are also collected for sale and consumption. Unfortunately, many of the naturally occurring varieties of mushroom are poisonous. Hence, people collecting wild mushrooms must be able to distinguish poisonous varieties from those that are edible. To determine if a mushroom is poisonous, boil the mushroom in water, then feed the juice and mushroom to test animals. If the test animals become sick or die, the mushroom is most likely poisonous.

Mushrooms grow naturally in moist, humid environments. Other environmental factors (i.e., temperature, growing medium, light) are also important to varying degrees, depending on the variety of mushrooms cultivated. For example: oyster and angel mushrooms prefer warm, moist climates; wood ear mushrooms like hot, humid weather, and; straw mushrooms require composting organic material as a substrate and relative darkness for proper growth. As one might expect, mushroom varieties native to Thailand grow best in the humid conditions of the rainy season.

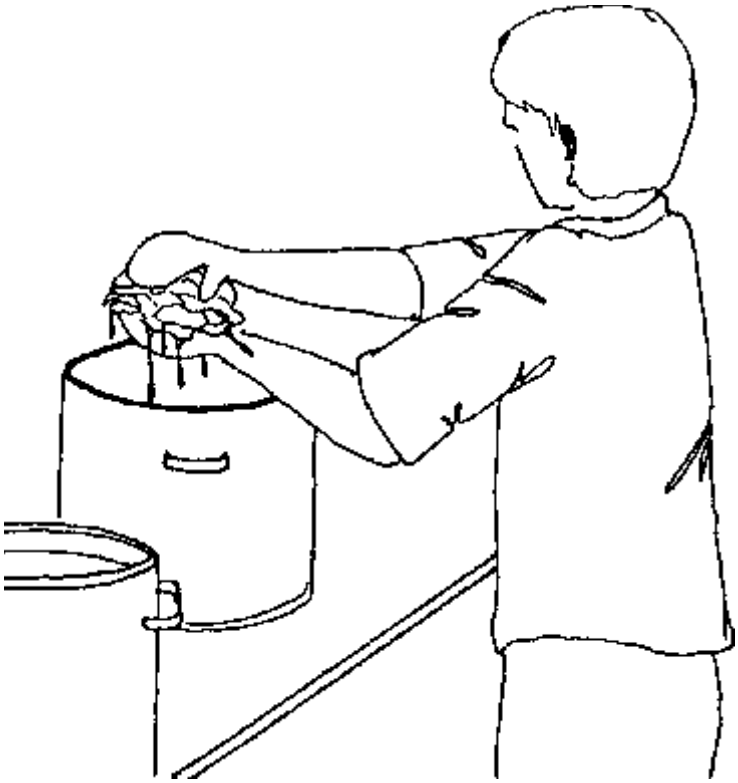
The market price of mushrooms fluctuates according to the season. During the rainy season, when the supply of both naturally occurring and commercially grown varieties of mushrooms is plentiful, the price is usually low. Conversely, during the dry season when the weather is not conducive to mushroom growth, the supply of mushrooms drops substantially and the market price climbs.

The market price in Ubon Ratchathani Province for straw, angel and oyster mushrooms ranges from B18-40 per kilogram annually, and from B25-60 per kilogram for wood ear and abalone mushrooms. Many producers of angel, oyster, abalone and wood ear mushrooms sell their produce directly to local restaurants rather than in markets due to the large volume of mushrooms consistently purchased by restaurant owners. This saves time for mushroom growers and simplifies marketing the mushrooms.

Each of the commercially grown varieties of mushrooms mentioned is sold fresh, except for the wood ear variety which can be sold fresh or dried. This offers the cultivator of wood ear mushrooms greater marketing options. During periods of high supply and low market price, growers can dry and store their mushrooms, delaying sales until supply is lower and prices are higher. Additionally, dried wood ear mushrooms are nonperishable and growers can send them to markets that are a great distance from the production site. Approximately 600-700 grams of fresh wood ear mushroom will yield 100 grams of dried mushrooms. The market price for dried wood ear mushrooms in Ubon Ratchathani Province ranges annually from B100-160 per kilogram.

Although angel, oyster and abalone mushroom varieties cannot be sold dried, they can, like wood ear mushrooms, be sent to distant markets if prepared in the following manner: blanch the mushrooms by dipping them in warm water, then immediately place them in a salt water solution (1 kg of salt per 20 liters of water). This solution preserves the mushrooms during shipment to the market for sale.

Figure 2: Blanching Mushrooms



Thailand also exports mushrooms to several countries, Taiwan being the largest importer. Many of the exported mushrooms are grown in Pon District, Khon Kaen Province, where there is a Taiwanese-owned straw mushroom canning factory in operation. The canning factory personnel give advice to local farmers concerning the cultivation of straw mushrooms and provide the farmers with a market for their produce, buying all mushrooms for B18 per kilogram.

Sale the mushrooms

2. Mushroom cultivation

The mushrooms commercially grown in Thailand each have different environmental requirements that must be met if maximum production is to be achieved. Some varieties may require more darkness or more humidity than others. Others may need high temperatures and/or windless conditions for maximum production, while still others are relatively insensitive to temperature and/or wind fluctuations. Nonetheless, all varieties of mushrooms require that growers follow certain common steps in order to successfully cultivate mushrooms. These steps are as follows:

1. A pure mushroom culture is developed in a Potato-Dextrose-Agar (PDA) mixture from a mushroom spore of the desired variety;
2. "Mother spore" is prepared on a grain substrate;
3. The mother spore is propagated on organic material, and;
4. Mushroom spawn, commonly referred to as mushroom "spore," is planted and cared for in such a way as to achieve maximum production.

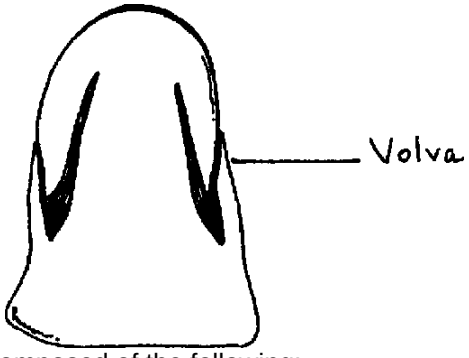
(Note: Mushroom growers in Thailand rarely complete steps 1, 2 and 3 as the PDA, mother spore and spawn of the commonly grown mushroom varieties are easily cultivated and sold commercially at low cost. Therefore, local growers might only complete step 4.)

3. Mushroom spawn propagation

The first step in the propagation of mushroom spawn is the development of a pure mushroom culture on a Potato-Dextrose-Agar (PDA) mixture. The materials needed to develop the pure mushroom culture are as follows:

1. Mushrooms of the desired variety. Use fresh, large healthy mushrooms. Especially desirable are mushrooms with the volva still intact (i.e., mushrooms that have not yet opened into and umbrella shape as seen in Figure 3).

Figure 3: MUSHROOM with Volva Still Intact



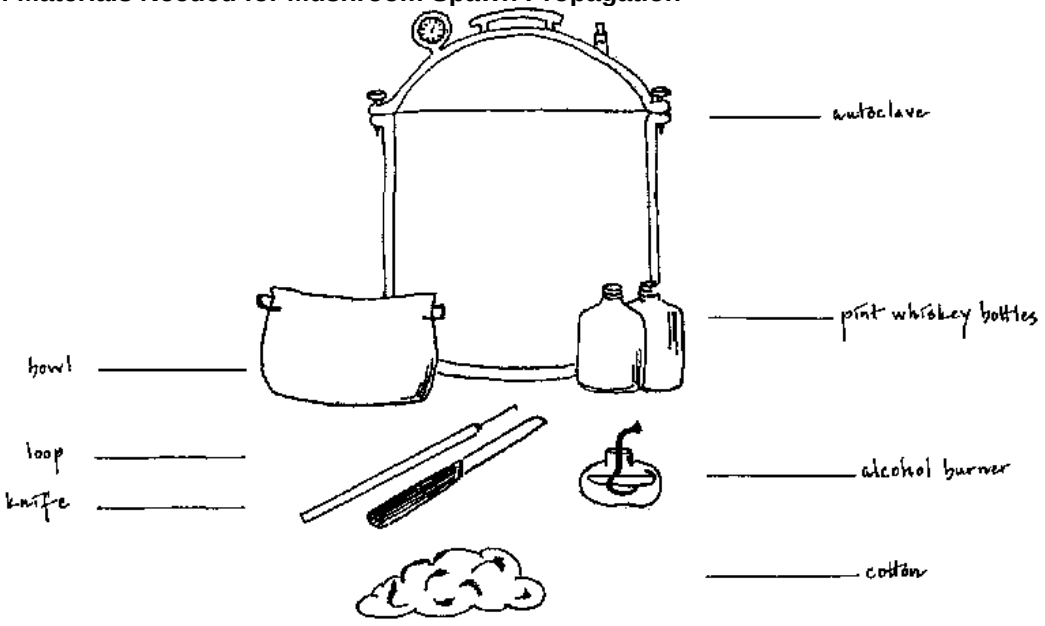
2. Potato-Dextrose-Agar media composed of the following:

water	1,000 ml
potato	200 g
agar	20 g
dextrose	20 g

3. Pint whiskey bottles
4. Cotton or kapok
5. Paper (newspaper is best) and rubber bands
6. Propagation hood
7. Knife
8. Autoclave (with at least a 200 pounds/in^2 (psi) capacity)

9. Inoculating loop
10. Alcohol burner and matches
11. Cheese cloth
12. Mixing bowl

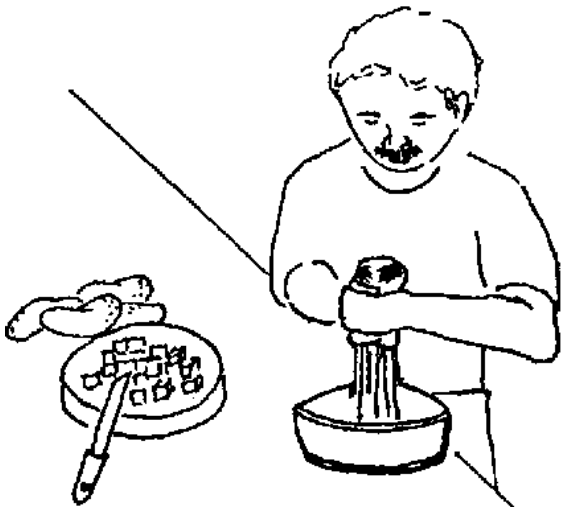
Figure 4: Materials Needed for Mushroom Spawn Propagation



Making potato-dextrose-agar mixture

With these materials at hand, the pure mushroom culture can be developed. The process to develop the culture is quite simple. The first step is to make the PDA medium. This is done by peeling and cutting 200 g of potatoes into small cubes and cooking them in 1,000 ml of water. After allowing the potatoes to cool, use cheese cloth to strain the liquid into a bowl.

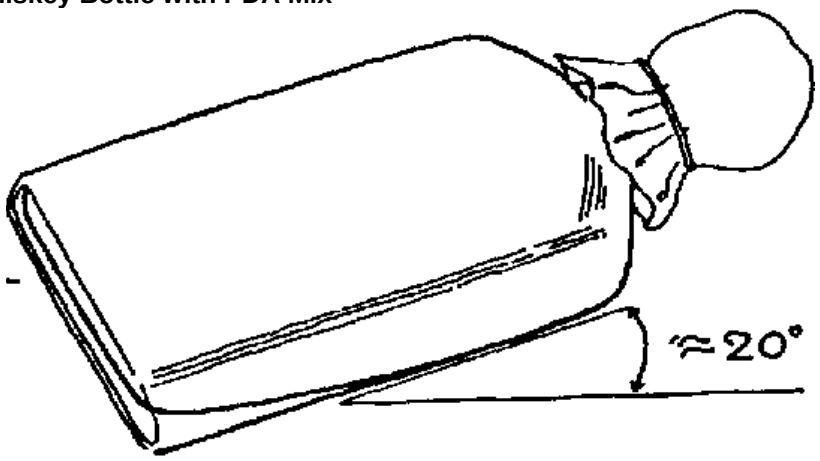
Figure 5: Straining Potatoes



Next, add 20 g of dextrose and 20 g of agar to the liquid and heat the mixture until the agar dissolves. After the agar has dissolved, strain the mixture and, if the liquid collected is less than 1,000 ml, restore the liquid to 1,000 ml using boiled water (allow the water to cool before adding to the collected liquid). Pour a small amount of this PDA mix into the clean pint whiskey bottles, filling the bottles approximately one fifth full. Close the bottles with clean cotton or kapok plugs, using paper to cover the cotton and

create a tight yet breathable seal. A rubber band should be used to secure the paper at the neck of the bottle. Next, sterilize the bottles and PDA mixture in an autoclave for 30 minutes at 15-18 psi. Following sterilization, remove the bottles from the autoclave and allow them to cool briefly (30-90 seconds) in an upright position. This is done to allow some of the condensation in the bottles to dissipate before placing the bottles in the desired slanted position. If the bottles are placed in a slanted position immediately following sterilization, condensation in the bottles might cause large air bubbles to appear in the PDA, reducing the effectiveness of the PDA as a mushroom growing medium. After allowing some of the condensation in the bottles to dissipate, place the bottles in a slanted position, as shown in Figure 6, and allow the PDA to congeal and cool to ambient temperature.

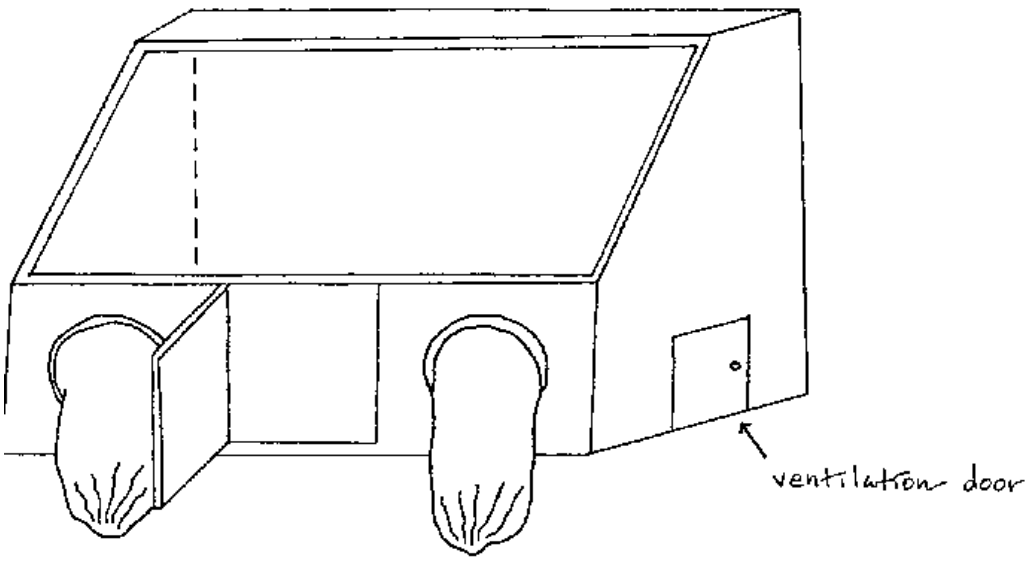
Figure 6: Pint Whiskey Bottle with PDA Mix



Inoculation of potato-dextrose-agar mixture

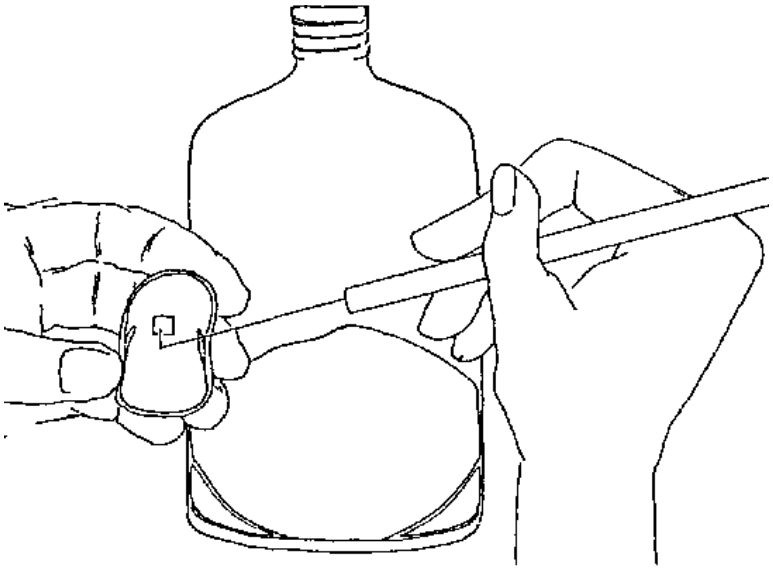
With the PDA prepared, placed into bottles and sterilized, inoculation of the PDA can begin. Inoculation must be done under sterile conditions to ensure the development of a pure mushroom culture. This is done by using a propagation hood (see Figure 7 and Appendix A). A propagation hood is an airtight box in which spore can be moved from one growing medium to another under aseptic conditions (i.e., free of all germs that may attack the pure mushroom culture). The hood is equipped with two glove holes in which the propagator places his/her hands when manipulating propagation equipment to prevent contamination of the box's contents. The hood should be thoroughly disinfected before each use (use bleach, methyl alcohol or formalin) so that conditions within the hood are truly aseptic. Likewise, all materials to be placed in the box during propagation activities should also be disinfected (i.e., bottles with PDA, alcohol burner, knife, inoculating loop).

Figure 7: Propagation Hood [1]



[1] Adapted from Mushroom Culture in Thailand, by Deeprom Chaiwongkeit. April, 1985. Department of Microbiology, Kasetsart University, Bang Kaen, Bangkok, p. 35.

Figure 8: Inoculation of PDA with Internal Tissue



With the hood and propagation tools thoroughly disinfected, place the PDA, mushrooms, alcohol burner, matches, knife and inoculating loop in the hood and close the box tightly. Next, use the alcohol burner to sterilize the knife and inoculating loop.

After allowing the knife and inoculating loop to cool, cut out a small piece of internal tissue from a mushroom; internal tissue from the stipe or gills of the mushroom may be used. (See Figure 8 above.) Be sure to use only internal tissue, as external tissue may be contaminated.

Using the inoculating loop, place the tissue on the center of the PDA in the bottles and recap the bottles as done previously, using a cotton plug, paper and rubber band. Remove the sealed bottles from the hood, place them in a dark room to develop into the pure mushroom culture.

Straw mushroom cultures are commonly left in the dark room for 5-7 days and develop best at a temperature of 34-38°C. Cultures of angel, oyster, abalone and wood ear mushroom varieties require 10-

15 days of darkness and incubate best at 24-26°C. (Note: The temperatures given are optimum temperatures. Colder temperatures will slow growth of the culture, while higher temperatures might damage the mushroom culture.)

Growth medium preparation: Mother spore

After the incubation period, when the PDA is covered with mycelium (very small white threads), the pure mushroom culture can be used to make the mother spore. The materials needed to complete this step are:

1. PDA culture
2. Sorghum grain
3. Pint whiskey bottles
4. Cotton
5. Paper and rubber bands
6. Propagation hood
7. Autoclave
8. Inoculating loop
9. Alcohol burner
10. Knife

Figure 9: Steaming Sorghum Grain

The procedure used to make mother spore is not complicated. First, soak the sorghum grain in water for approximately 12 hours. Then steam the grains until they are approximately 25 percent cooked, or are just beginning to crack open. Next, fill a clean pint whiskey bottle to one half full with the prepared grain and close with a cotton plug, paper and rubber band. Sterilize the bottle and grain in an autoclave at 18-20 psi. for 45 minutes, and allow to cool to ambient temperature.

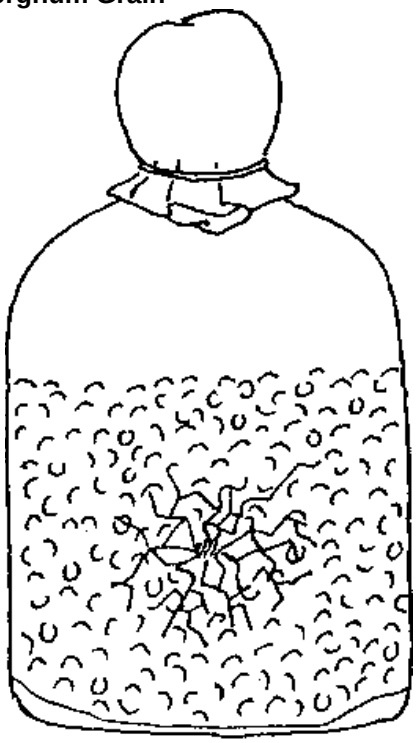
Inoculation of mother spore growth medium

After the bottles have cooled, move all inoculating materials into the disinfected propagation hood (i.e., PDA culture, sorghum grain, knife, inoculating loop, alcohol burner, cotton, paper and rubber bands). Use the alcohol burner to sterilize the knife and inoculating loop, allow them to cool, then cut a small section out of the pure PDA mushroom culture and place it in the bottle containing the grain. Re-plug the bottle using cotton, paper and rubber band, as done previously, Remove the sealed bottles from the hood and store in a dark place in order to allow the culture to develop.

Cultures of straw mushrooms require 5-7 days storage at 34-38°C for optimum development, while the other varieties require 10-15 days storage at 24-26°C. (Note: Again, the temperatures given are optimum temperatures. Lower temperatures will slow the development of the culture, while higher temperatures might damage the culture.)

With the sorghum grain in the bottle(s) covered with mycelium, transfer it to sterilized compost growing media collected in plastic bags. Many items can be used as growing media, including rice straw, leucaena leaves, water hyacinth, horse manure, sugarcane refuse, ground corn cobs, coconut shell dust and para rubber tree pulp. The substance one uses depends on several variables, including: variety of mushroom to be propagated, substrates locally available, cost of substrates and the ease or difficulty of using a given substrate verses another. This handbook cannot include all the procedures used with each kind of growing medium. Instead, one procedure to propagate angel, oyster, abalone and wood ear mushroom spawn and another procedure to propagate straw mushroom spawn will be described, illustrating the different techniques used to propagate these two groups of mushrooms. Other growing media would be used in similar fashion to the substrates described.

Figure 10: Mycelium Covering Sorghum Grain



Growth medium preparation: Angel, oyster and abalone mushrooms

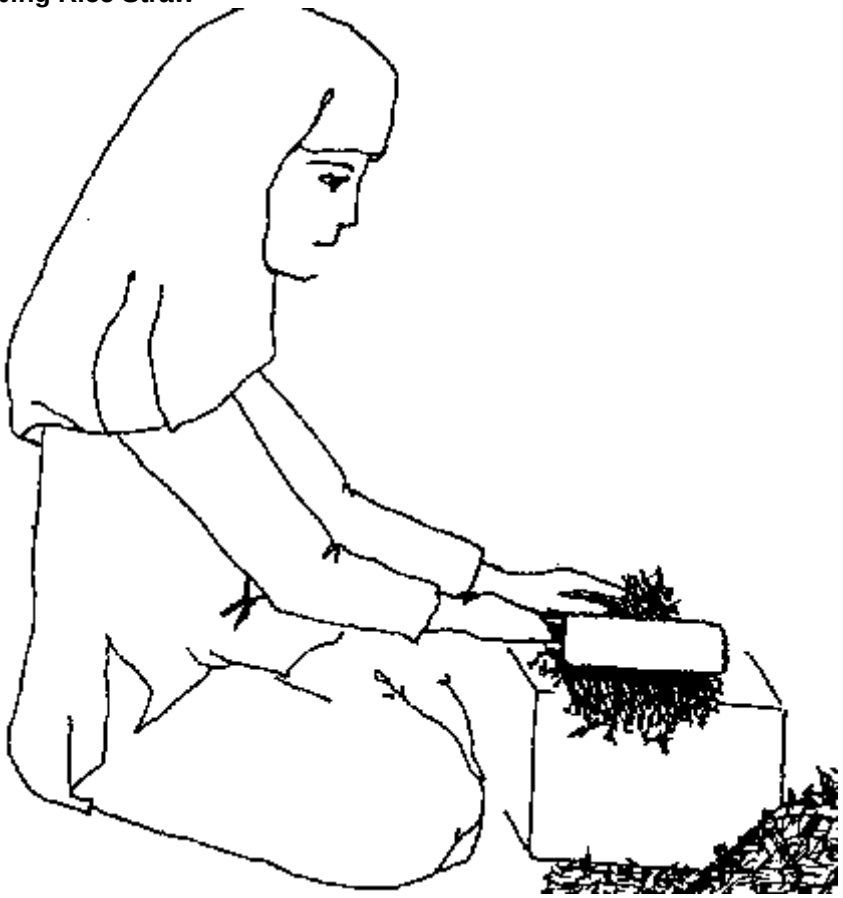
Commercial growers of angel, oyster and abalone mushroom spawn normally use a para rubber tree pulp based substrate as their growing medium, as this substance has proven to yield the best results. However, para rubber tree pulp is not readily available to most Thai farmers and is not a viable choice as a growing substrate for them. (For more information concerning the uses of para rubber tree pulp and other substances used as growing media, refer to Appendix C.)

A far more commonly available item that can be used as a growing medium--and one that yields good results--is rice straw. A rice straw based growing medium is easy and inexpensive to make using the following procedure.

Mix 100 parts rice straw chopped to approximately 3-5 inches long, 2-3 parts calcium carbonate ($CaCO_3$), 5 parts urea (46-0-0), 2 parts magnesium sulfate ($MgSO_3$), and enough water to thoroughly moisten the

resulting pile. The calcium carbonate, urea and magnesium sulfate may be combined in water before adding to the rice straw to facilitate the mixing process and ensure a good, even distribution of materials.

Figure 11: Chopping Rice Straw

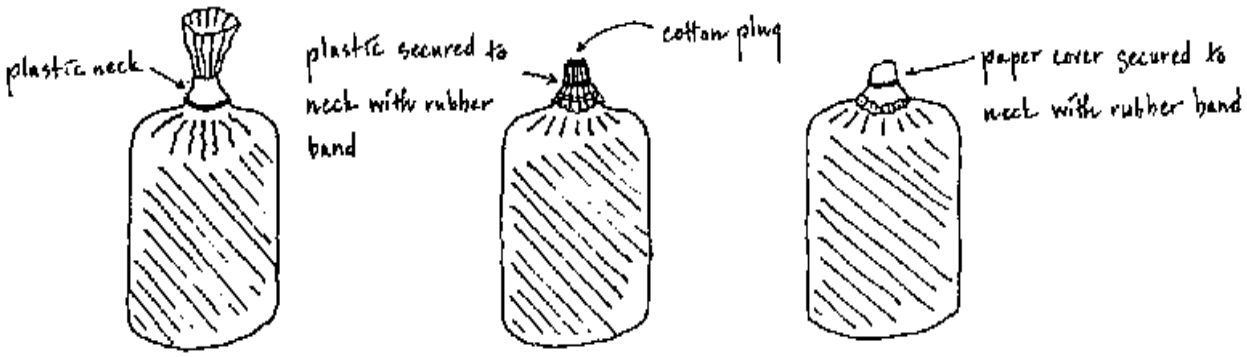


Turn the pile twice daily, mixing in five parts rice bran on the seventh day. When the strong scent of ammonia-generated by the pile has disappeared, and the pile no longer heats up after turning (generally around the seventh or eighth day), place the compost into 18 x 28 cm, 0.1-0.12 mm thick, heat resistant plastic bags. These bags are available at major mushroom spawn outlets in Bangkok.

The moisture content of the compost placed in the bags determines to a great degree the speed at which the mushroom spawn will develop. Spawn will grow slowly (if at all) in compost that is too wet or too dry. To check if the compost has the right moisture content, squeeze the compost into a ball shape; if water drips from the compost on squeezing, the compost is too wet. If the ball of compost breaks apart easily when released, the compost is too dry (see Figure 12 below).

Figure 12: Checking Moisture Content of Substrate

Figure 13: Sealing Plastic Bag of Spawning Substrate



Pack the compost firmly in the bags in order to promote rapid spawn growth. Leave approximately 3 inches of plastic at the top of the bags, over which are placed plastic tubes or "necks," available at most mushroom spawn outlets. Fold the tops of the bags down over the plastic necks, fastening the plastic to the necks with a rubber band as shown in Figure 13. Plug the neck with cotton and seal the hole shut with a piece of paper secured at the neck with a rubber band.

Sterilize the compost before adding the grain with the mycelium. The compost bags can be sterilized using an autoclave or an oil drum. If using an autoclave, sterilize the compost at 15-20 psi for one hour, then allow to cool to ambient temperature. An oil drum--a piece of equipment more commonly available to farmers than an autoclave--would be used to sterilize the bags in the following manner:

1. Place the oil drum on rocks or over a small pit so that a fire may be built beneath it.

2. Place a metal grate inside the drum, positioning it approximately 1 foot from the bottom.

3. Fill the drum with water to a level about 6-7 inches below the level of the grate.

4. Using heavy paper, cardboard or straw matting, line the walls and grate inside the drum to ensure that the plastic bags will not burn during sterilization.

5. Place the compost-filled bags--about 45-60 bags depending on the size of the drum--onto the lined metal grate, stacking them to the top of the drum.

6. Seal the drum tightly with a lid that has a hole, or holes, to allow steam to escape (see Figure 14).

7. Build a fire under the drum and steam the compost-filled bags for 2-3 hours.

8. Remove the bags from the drum and allow to cool to ambient temperature. Discard all bags that were damaged during the sterilization process. (Note: For information concerning the construction of an oil drum autoclave, refer to Appendix B.)

Figure 14: Metal Sterilization Drum with Compost-Filled Plastic Bags

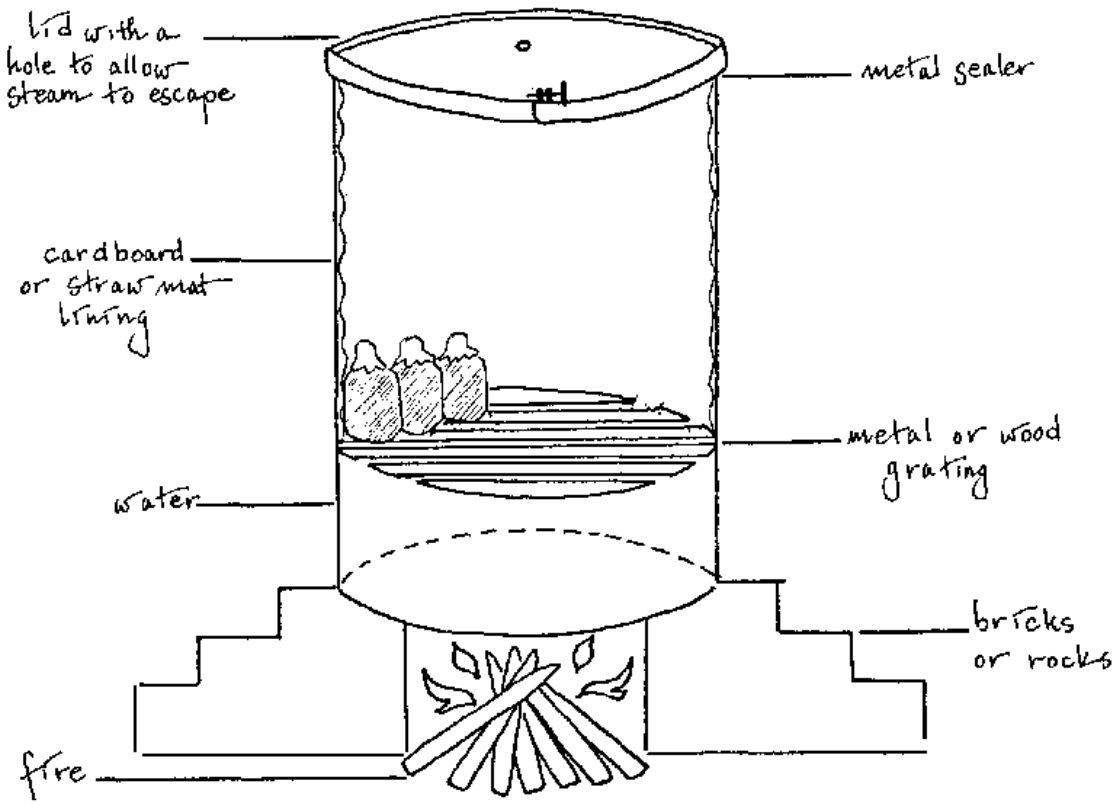
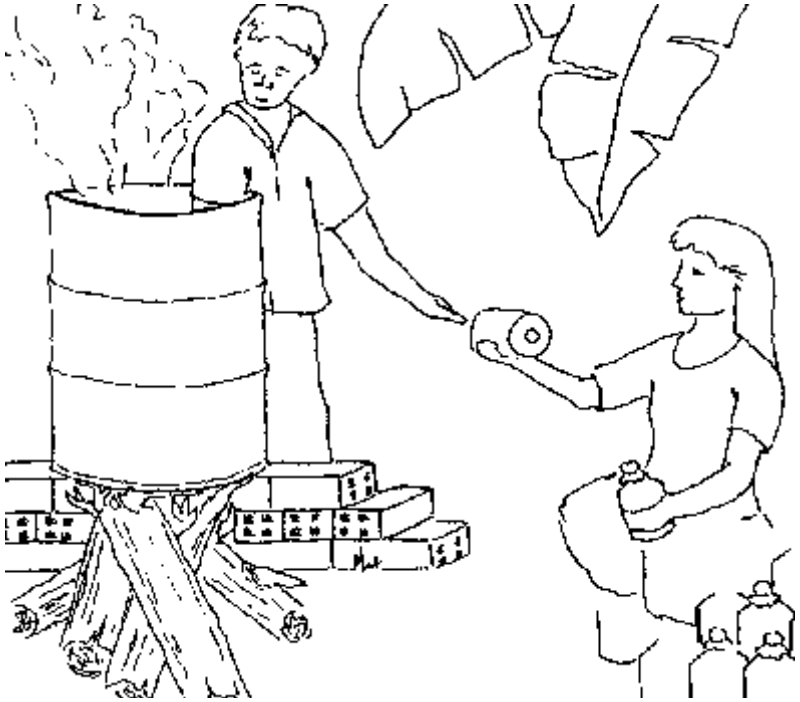


Figure 15: Sterilization of Mushroom Spawn Using an Oil Drum autoclave,

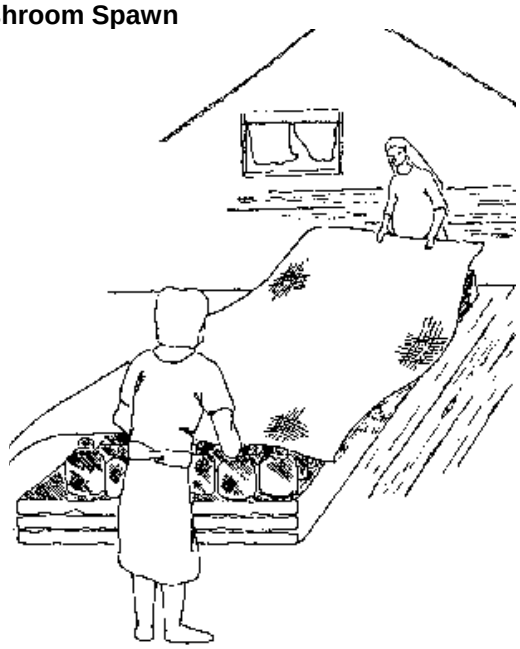


Inoculation of angel, oyster and abalone mushroom growth medium

After the bags have cooled, the grain and mycelium may be added to them. Do this in an enclosed area where conditions are sanitary. It may also be done in a propagation hood to ensure a totally sterile transfer. The grain and mycelium can simply be shaken out of the bottles and dropped directly into the bags, or a knife may be used. Any equipment used to transfer the grain and mycelium to the bags should be sterilized with the alcohol burner before use to ensure that unwanted bacteria does not come in contact with the mycelium or the sterilized compost. Do not touch the grain or mycelium as this will also contaminate it.

After placing the grain and mycelium in the bags (approximately 10-20 seeds per bag), shake the bags in order to spread the seeds evenly over the top of the compost and reseal them using cotton, paper and rubber bands. Incubate the bags in a dark place for 25-35 days at 24-26°C. (Note: Again, this is an optimum temperature. Cooler temperatures will slow spawn development, while higher temperatures might damage the spawn).

Figure 16: Incubation of Mushroom Spawn



After mycelium have totally filled the bags (the bags' contents will be totally white in color), the bags can be cultivated or sold to other growers for cultivation. (For more information concerning the cultivation of angel, oyster and abalone mushrooms, refer to the section entitled Angel, Oyster and Abalone Mushroom Cultivation in Plastic Bags, p. 39.)

Growth medium preparation: straw mushroom

Like angel, oyster and abalone mushroom spawn, straw mushroom spawn can be grown on many different substrates. Commercial growers of straw mushroom spawn most commonly use a horse manure based growing substrate to propagate their spawn. Horse manure is used because it has the most complete supply of the nutrients needed to stimulate rapid spawn growth of the media that are economically feasible to use. However, horse manure is not often available to most Thai farmers, and so is not a viable choice as a growing medium for them. (For more information concerning the uses of horse manure and other substances used as growing media, refer to Appendix E.)

Two items more commonly available that car. be used together as a growing medium are water hyacinth and leucaena leaves. They are prepared as a growing medium using the following method. Gather 10 kg of dried water hyacinth and 1-3 kg of dried leucaena leaves, chop into small (approximately 1 cm long) pieces and mix together. Add 10-15 liters of water and mix well. As with the rice straw compost mixture, the moisture content of the mix determines to a great degree the speed at which the mushroom spawn will develop. To check if the compost has the right moisture content, squeeze the compost into a ball

shape; if water drips from the compost on squeezing, the compost is too wet. If the ball of compost breaks apart easily when released, the compost is too dry. Once the compost has the correct moisture content, fill 18 x 28 cm plastic bags one-half full with the water hyacinth-leucaena leaf mix and sterilize in an autoclave at 20 psi for one hour (an oil drum may be used to sterilize the growing substrate, using the method described in the section entitled Growth Medium Preparation: Angel, Oyster and Abalone Mushrooms, p. 15).

Figure 17: Inoculation of Growing Substrate

Inoculation of straw mushroom growth medium

After allowing the bags to cool to ambient temperature, the growing medium is ready for the sorghum grain with mycelium to be added. This step should be done under sanitary conditions in the same way as that done for cultivation of angel, oyster and abalone mushroom spawn as described in the section entitled Inoculation of Angel, Oyster and Abalone Mushroom Growth Medium, p. 20. After placing the 10-20 grains of sorghum with mycelium in the bags, fold the tops of the plastic bags over one or two times, seal with two or three staples, and allow them to incubate in a dark place at ambient temperature for 7-9 days, by which time the white threads of the mycelium should be seen spreading throughout the bag. The resulting mixture in the bag --straw mushroom spawn--is then planted or sold to growers for cultivation. (For more information concerning the cultivation of straw mushrooms, refer to the section entitled Straw Mushroom Cultivation in Beds, p. 25.)

The propagation of mushroom spawn from a mushroom is easily done on a small scale. The necessary materials are often readily available and the techniques used are not difficult to master. However, it is difficult for most growers to propagate large amounts of good, healthy mushroom spawn without a large investment of time and money. It is often best for farmers to purchase the sorghum grain with mycelium (available at most mushroom spawn outlets) and propagate their own spawn from this source, or simply purchase their spawn from large commercial producers who sell spawn very inexpensively and are able to guarantee the quality of the mushroom spawn. Nonetheless. spawn propagation techniques should be taught to all growers in order that they may better understand the complete life cycle of the mushrooms they are producing. A better understanding of their crop may lead to higher yields.

Once a grower has cultivated or purchased his spawn, he is ready to cultivate mushrooms. As previously mentioned, different varieties are cultivated in different ways, using various growing media. The mushroom varieties commercially grown in Thailand are cultivated in three main ways: in beds, in plastic bags and in wooden logs.

4. Straw mushroom cultivation in beds

Straw mushrooms are most commonly cultivated in beds in Thailand. Angel and oyster mushrooms are also grown in beds, but much less often.

Materials needed

The materials needed to cultivate straw mushrooms in beds are the following:

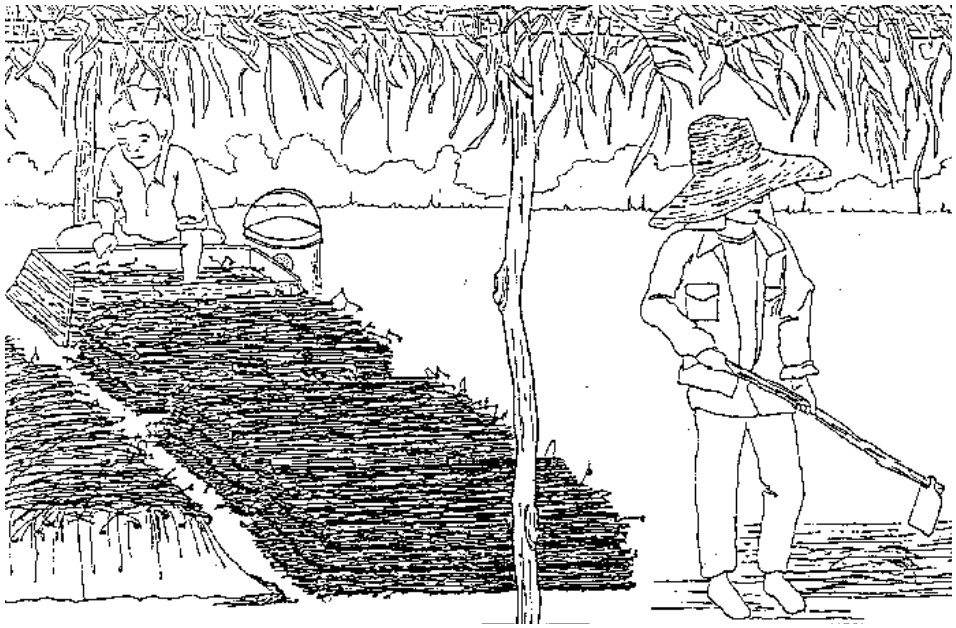
1. Rice straw, or dried water hyacinth as the growing substrate. (Note: With rice straw, use the bottom portion of the stalk left in the fields after harvest. The bottom portion is preferred because it absorbs and retains water better than the upper portion harvested with rice grain and offers a more humid atmosphere for mushroom growth than the tops of the stalk which dry rapidly.) Other substances that may be used include: banana tree trunks and leaves, maize residues, mung bean husks and para rubber tree pulp.

2. Supplementary food made from dry chicken, pig, cattle or buffalo manure mixed in a 1:1 ratio (by volume) with chopped or shredded dry water hyacinth or rice straw. The mix should be watered until thoroughly moistened. Cotton and/or kapok may also be added to the mixture.

3. Spawn. Choose spawn that is sweet smelling and healthy looking with long white mycelium threads visible throughout the growing substrate. (Note: For more information concerning the purchase and handling of mushroom spawn refer to Appendix F.)

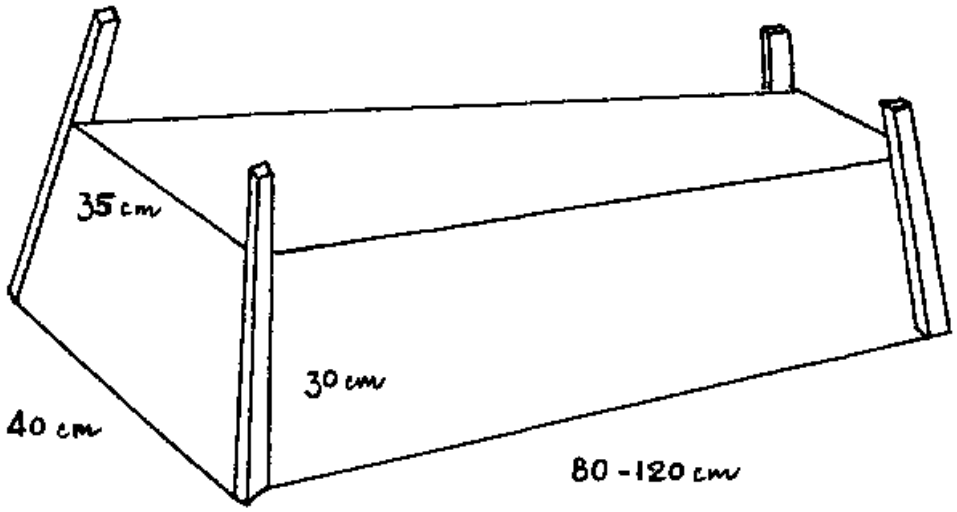
4. Watering can and water. Be careful not to use chlorinated water, as it will kill the mushroom spawn. If only chlorinated water is available, it can be dechlorinated by collecting it in a jar and allowing the water to sit for two days. The chlorine dissipates and the water is acceptable for use.

Use of the wooden mold



5. Wooden mold, approximately 80-120 cm long, 40 cm wide at the base, 35 cm wide at the top (to ease removal of the wooden mold once the bed has been constructed).

Figure 18: Wooden Mold



6. Clear plastic sheet and rice straw to be used to cover the beds.

7. Hoe.

Cultivation steps

The steps required in the cultivation of straw mushrooms are as follows:

1. Soak the rice straw or dried water hyacinth overnight in water for best results during the cold and hot seasons. During the rainy season, it is possible to soak the straw for only 15-20 minutes and achieve good results, although a longer soaking period is preferable.

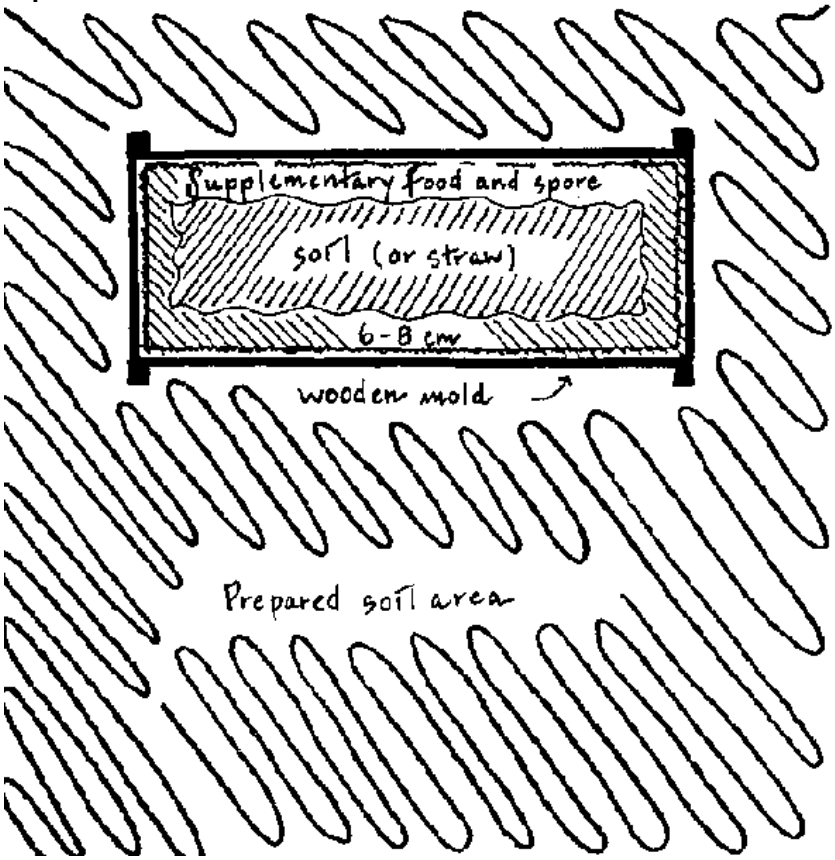
Figure 19: Soaking Rice Straw

2. Prepare the soil where the beds are to be made by spading an area approximately 120 cm wide 6-8 cm deep and 7 meters long. Expose this area to the sun for 3-4 days in order to kill any existing bacteria and/or fungi. During the rainy season construct a raised bed 5-10 cm above the surrounding soil level to prevent flood damage during heavy rains.

3. Place the wooden mold at one end of the prepared soil area and sprinkle the supplementary food around the inside border of the mold, creating a band of food approximately 6-8 cm wide and 1 cm thick.

4. Sprinkle one-third of a bag of straw mushroom spawn on the supplementary food, placing the majority of the spore next to the inside border of the wooden mold.

Figure 20: Bed Preparation



(Note: In this example, a bed composed of three layers is being made. Hence, the use of one-third of a bag of spawn per layer. If the bed was composed of four layers, one-fourth of a bag of spawn would be used per layer. Five layers would require one-fifth of a bag per layer, and so on. Each bed constructed will use a total of one bag of mushroom spawn).

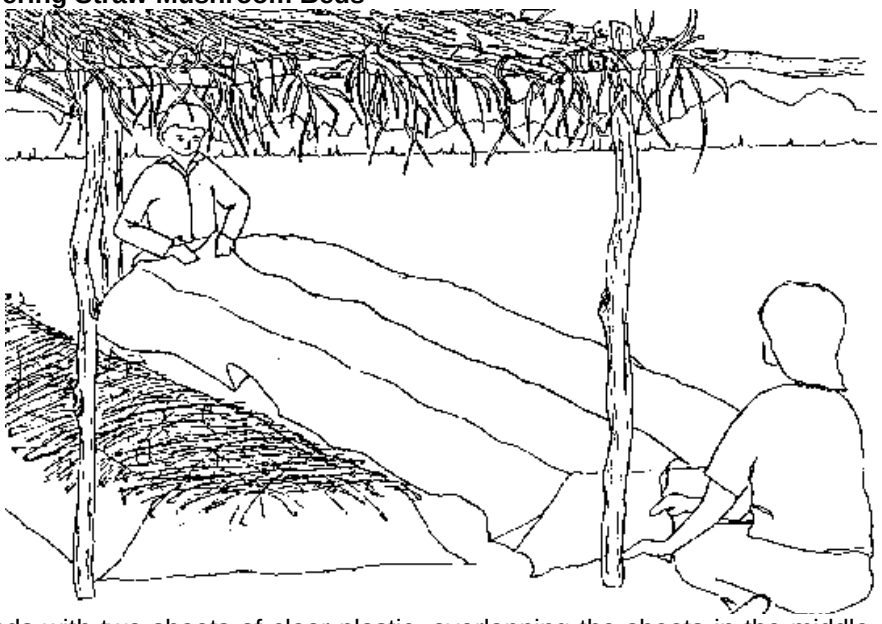
5. Place the presoaked rice straw or water hyacinth on top of the spawn-supplementary food layer. Press the straw or water hyacinth firmly into the bottom of the mold, filling the mold one-third full. This completes the first layer of the bed.

6. Repeat this procedure to complete subsequent layers, then water thoroughly with one or two buckets of water. The number of layers planted in one wooden mold varies according to the season: three layers in the hot season, four layers in the rainy season, and five layers in the cold season.

7. Remove the wooden mold and place it next to the first bed, lengthwise, leaving 12-16 cm between beds in the hot season and 8-10 cm in the cold and rainy seasons. Use the described method to plant as many beds as desired. Ten beds of straw mushrooms are commonly planted in one 7-meter row.

8. Loosen the soil between and around the beds in the row. Sprinkle supplementary food over this area and water thoroughly. Sprinkle one bag of straw mushroom spawn over the supplementary food between and around the beds in the ten-bed row.

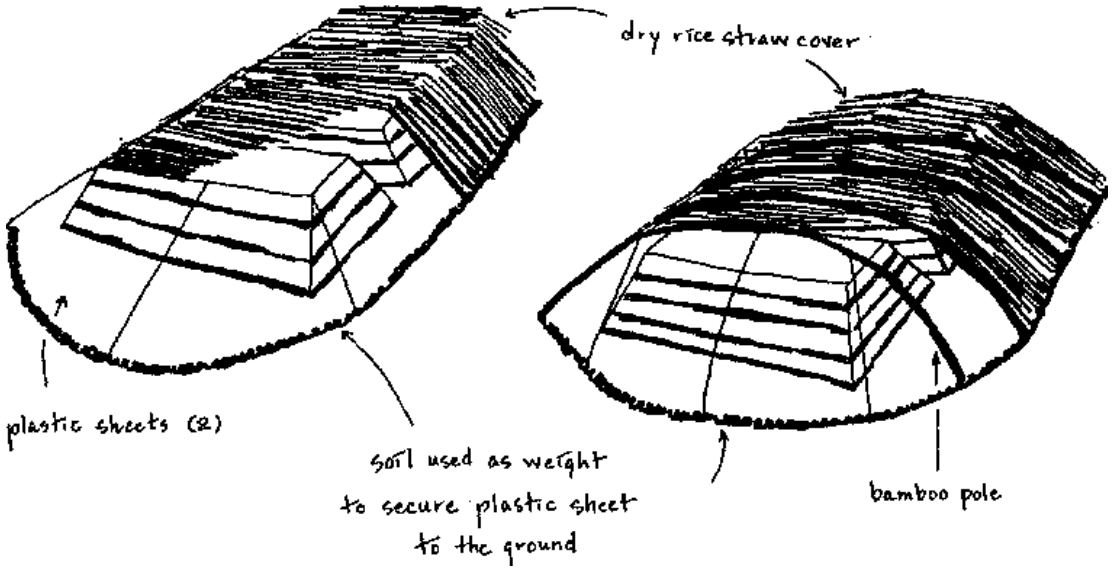
Figure 21: Covering Straw Mushroom Beds



9. Cover the beds with two sheets of clear plastic, overlapping the sheets in the middle of the beds. Be careful not to let the plastic sheets rest against the sides of the bed as this will inhibit mushroom growth and greatly reduce mushroom production. Bamboo sticks can be used as supports to keep the sheets from coming in contact with the sides (and tops, if desired) of the beds. Wood, rocks and/or dirt should be used to secure the edges of the plastic sheets to the ground (see Figure 21).

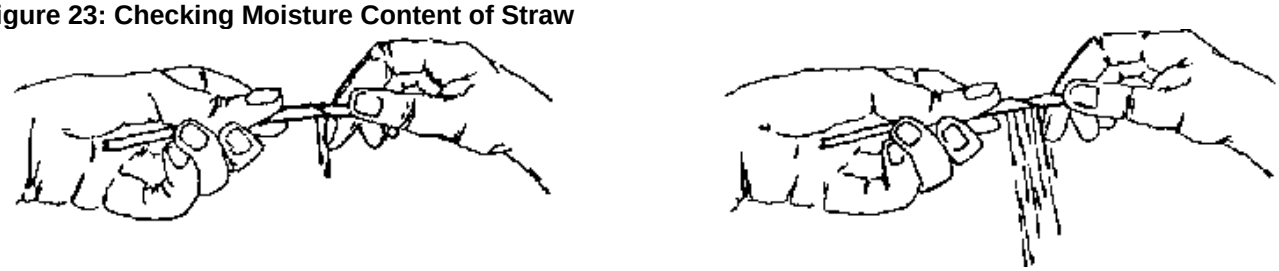
10. Cover the plastic sheets with dry rice straw, as shown in Figure 22. This will prevent direct sunlight from shining on the beds which is likely to kill the spawn. If desired, an additional roof of coconut leaves (or other suitable material) can be built over the beds to further protect them from excessive exposure to sunlight and heat. This roof should be built high enough above ground level to allow people to walk comfortably under it.

Figure 22: Protection for Cultivation Beds



11. Check the moisture content of the beds on day 4. This is done by taking a sample of rice straw from one of the beds (one or two pieces of straw is adequate, examine samples from several areas in the row of beds) and twisting it. If much water drips from the straw sample, the beds are too wet and need to be dried. This is done by opening the plastic sheets over the middle of the beds, leaving an open space 5-10 cm wide, the length of the row. This will allow air to circulate within the row, thereby decreasing moisture content. It is best to open the plastic sheets for 5-15 minutes during the early morning and/or late evening, when the sun is low in the sky. This procedure reduces the chances of sunlight-induced spawn kill.

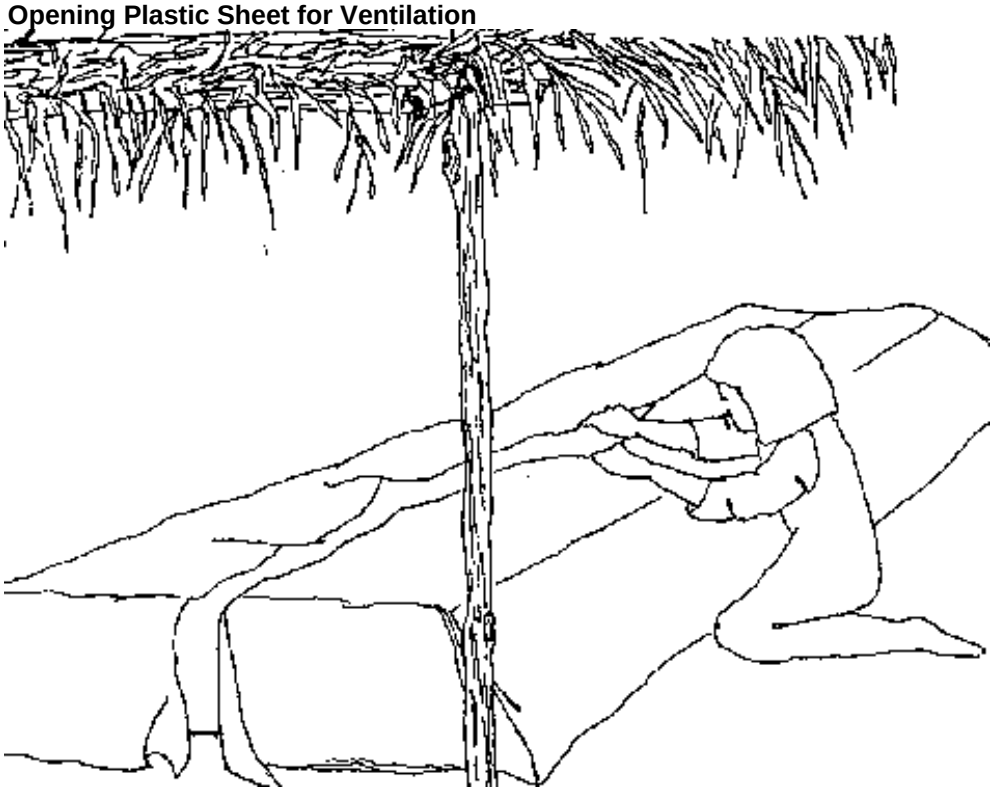
Figure 23: Checking Moisture Content of Straw



If 2-4 drops of water slowly fall from the twisted straw samples, the beds have adequate moisture. If no water drips from the straw, the beds are too dry and require watering. When watering, be careful to water around, not on, the beds.

12. If the weather is extremely hot (35°C and higher) during the first five days after planting, open the plastic sheets over the middle of the beds leaving an open space 5-10 cm wide the length of the row, as shown in Figure 24. This will allow air to circulate slowly within the row and prevent the spore from dying due to high temperatures. If the plastic sheets are opened, the moisture content of the beds should be closely monitored using the technique described in step 11.

Figure 24: Opening Plastic Sheet for Ventilation

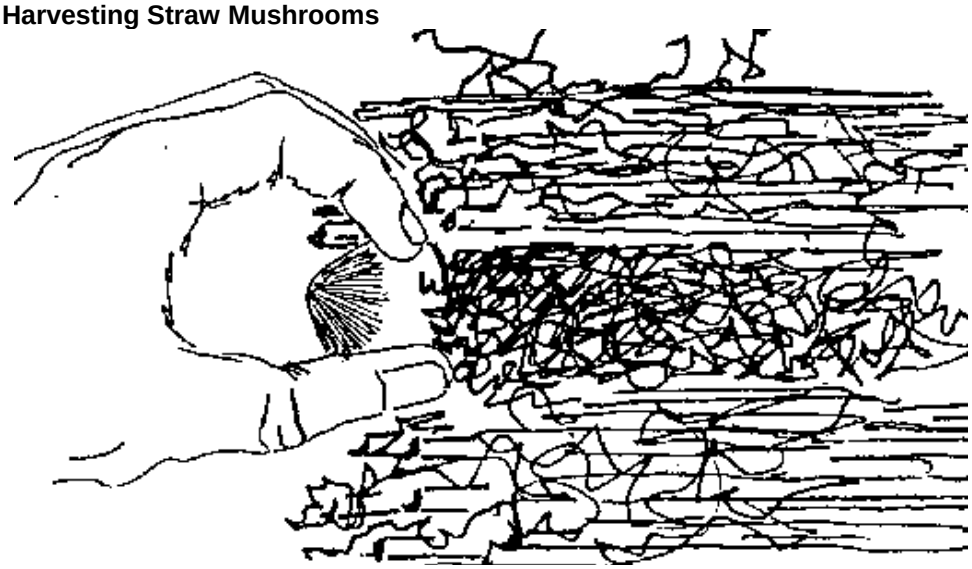


13. White thread-like mycelium and possibly small mushrooms might be seen growing in the beds after 5-8 days.

Harvesting

1. Harvest will begin 9-11 days after planting. Pick the mushrooms by twisting them at their base in the straw bed. Straw mushrooms should be harvested before the head of the mushroom fully emerges, since this type of mushroom will bring the highest price.

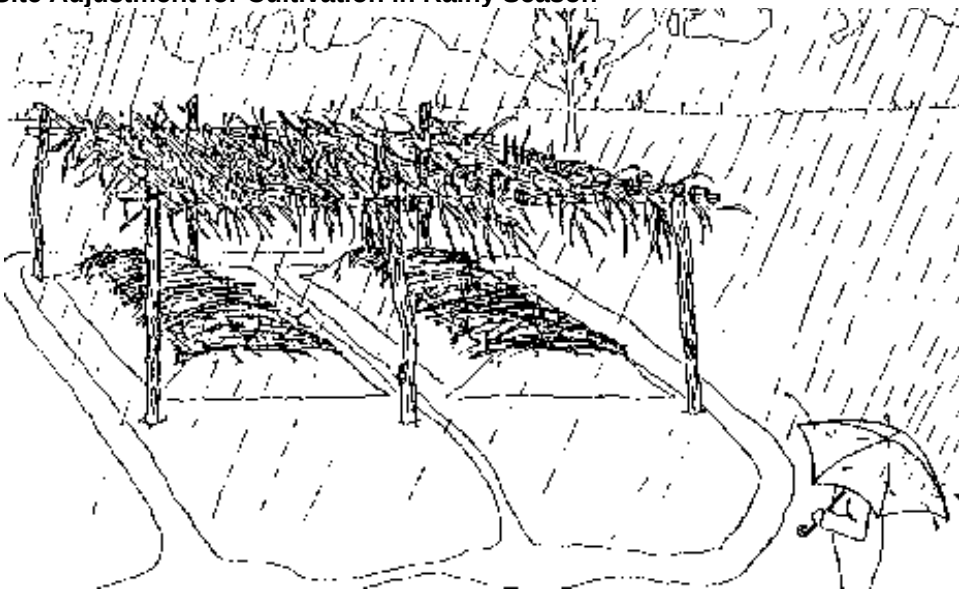
Figure 25: Harvesting Straw Mushrooms



2. Initial harvest will be complete in 2-4 days. Thereafter, the beds may be watered with plain water, or water enriched with nitrogen (use fertilizer, 25-5-5 vegetable and flower fertilizer, or any other water-soluble fertilizer with a high nitrogen content). Water on top and around the beds. Cover once again with plastic and straw, and after 2-7 days a second, smaller harvest may be possible. One bed should produce a total of 0.5 to 1.0 kg of consumable mushrooms.

This handbook cannot describe all the methods used in the cultivation of straw mushrooms. The method described above is one of the common methods practiced throughout Thailand. It is not the only way to cultivate straw mushrooms. Do not be afraid to experiment or try other methods not described in this handbook. Use common sense.

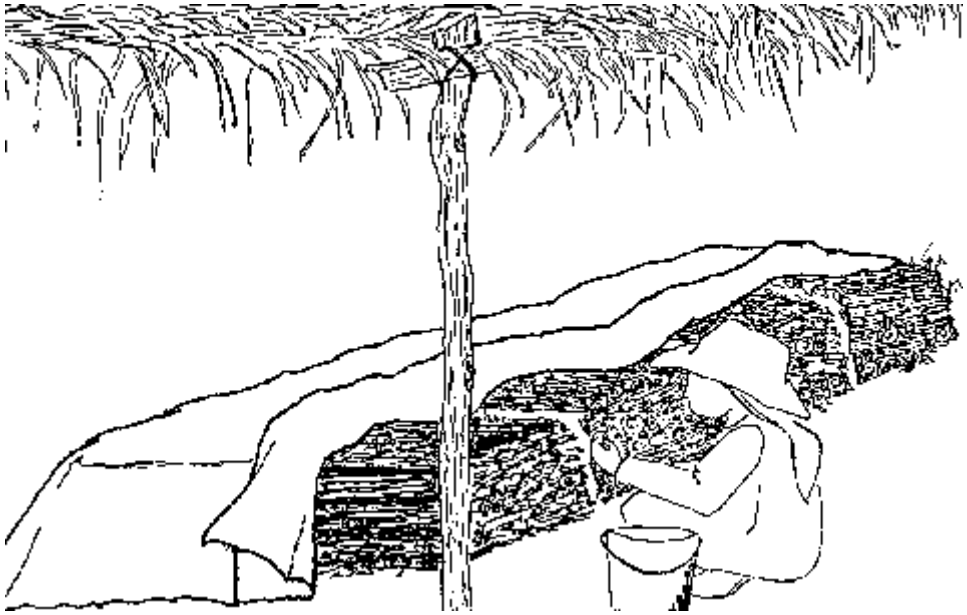
Figure 26: Site Adjustment for Cultivation in Rainy Season



Cultivation in rainy season

Straw mushrooms are usually grown in Thailand during the cool and hot seasons, following the harvest of rice. The reasons for this are obvious. First, the supply of rice straw is at its height and farmers are free to pursue other activities since their rice crops have been harvested. Second, because of the large number of producers cultivating mushrooms at the same time, supply is high and the market price is low during these seasons. Although it is possible to cultivate straw mushrooms during the rainy season, it is seldom done due to the lack of rice straw and farmer preoccupation with the rice crop. As one might expect, the market price for straw mushrooms is quite high during the rainy season. For example, in Ubon Ratchathani Province, prices may reach B40 or more per kilogram. Therefore, it may be worthwhile to encourage farmers to store rice straw for mushroom cultivation during the rainy season, or to use water hyacinth as the growing substrate. The technique used is the same as that described here, with the additional step of digging small channels between rows of beds in order to allow rainfall to drain away from the cultivation site, lessening the danger of flood damage to the beds. Farmers who are able to cultivate straw mushrooms successfully during the rainy season will be able to earn a good deal of extra income.

Storing rice straw for mushrooms cultivation



5. Angel, oyster and abalone mushroom cultivation in plastic bags

Most varieties of mushrooms commercially grown in Thailand produce best not in beds but in plastic bags. Angel, oyster and abalone mushrooms are varieties most commonly grown in plastic bags filled with composting organic matter. These mushrooms are easily grown. All that is required is mushroom spawn of the desired variety, a good place to cultivate the mushrooms and the labor necessary to water the mushrooms several times a day.

Materials needed

Unlike straw mushroom spawn, which is readily available in many districts throughout the country, angel, oyster and abalone mushroom spawn is sold only in Bangkok and larger upcountry provincial capitals (e.g., Khon Kaen, Chiang Mai, etc.) However, this should not pose a problem to potential growers as most, if not all, of the sellers of these varieties of spawn will send the spawn completely prepared and

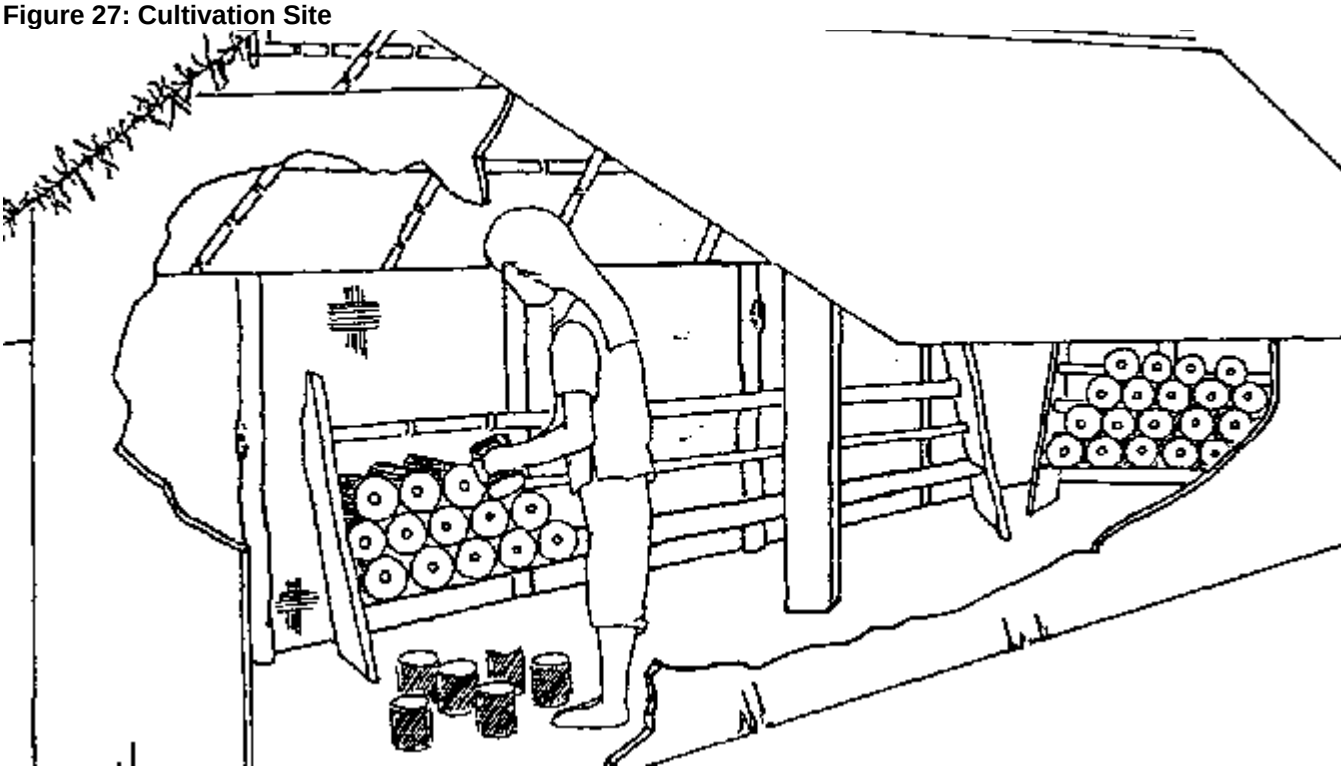
ready to be cultivated to all provincial capitals and most districts throughout the country at very little additional cost to the buyer.

Cultivation site

One of the most important steps in the cultivation of these mushroom varieties is the selection of the proper site for cultivation. The site must be warm and humid and have good ventilation. Bathrooms or areas near water storage jars are good sites, as water is always nearby and ventilation is usually adequate. However, these sites commonly limit the amount of spawn cultivated to several bags, lessening economies of scale and making profits more difficult to earn.

It is often best to convert an old chicken or pig house to a mushroom house or build a structure specifically for the cultivation of mushrooms. A large structure is not necessary: 4 x 3 meters is large enough for a beginning farmer. Obviously, if one wants to cultivate a large quantity of mushrooms, a larger house will be needed: an 8 x 4 meter house is large enough to cultivate 2,000-3,000 bags of mushroom spawn. While the length and width of the structure is not of great importance, the height of the building should be at least 2-2.5 meters. This allows for proper ventilation within the building, a necessary environmental factor for maximum mushroom production. The roof should be made of grass to further aid ventilation and help keep the house cool during hot days. The walls of the house can be made of grass or plastic. If grass is used, the grower will need to water the spawn more often as the moisture within the house will continually escape through the grass walls. If a good supply of water is not nearby, the farmer may choose to use plastic sheets to cover the walls of the house. The plastic (fertilizer bags or other plastic sheets of similar thickness can be used) will help keep conditions within the house humid, reducing the quantity of water needed to provide the mushrooms with the correct growing atmosphere. The floor should be of sand (3-8 cm thick, of any quality) in order to further increase the moisture retaining capacity of the house. (For further information concerning mushroom house preparation prior to cultivation, refer to the section entitled Mushroom Pests: Prevention and Eradication, p. 57).

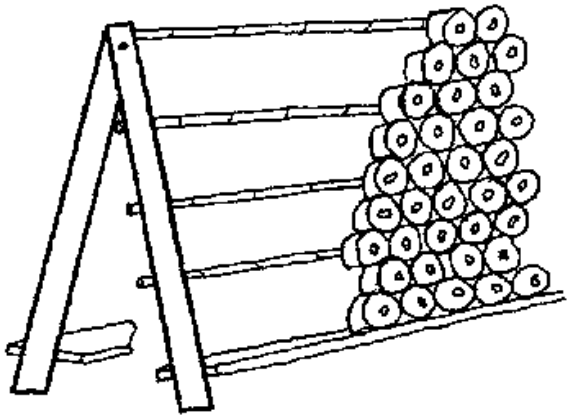
Figure 27: Cultivation Site



Shelves or an A-frame rack must be erected inside the house to hold the plastic bags of spawn during cultivation (see Figure 28). Shelves should be approximately 20 cm (or more) wide, as long as is desired, and at least 50 cm apart, as less distance between shelves will make harvesting the mushrooms more

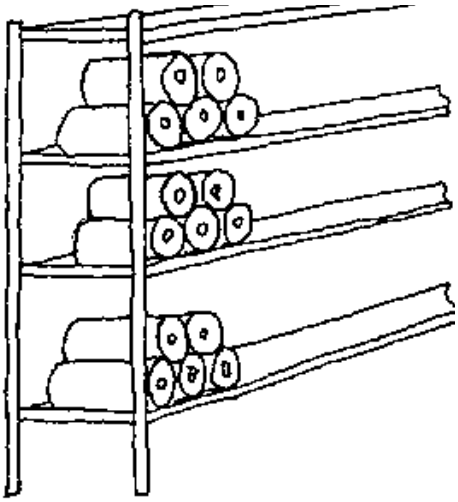
difficult. Two to five rows of mushroom spawn are usually stacked on one shelf, each bag of spawn lying on its side. If an A-frame rack is used, two shelves are built, one at the base of each side of the A-frame, and bamboo is used as back support for the bags of mushroom spawn. Again, the plastic bags of mushroom spawn are laid on their sides in rows, the first row placed on the shelves constructed at the base of the A-frame. Subsequent rows are stacked on top of this row, up to the top of the A-frame. Either structure will produce good results, although the A-frame is less expensive to construct and allows for more bags of spawn to be cultivated per unit area.

Figure 28: Example of Mushroom Cultivation: A-frame rack



mushroom cultivation on an A-frame rack

Figure 28: Example of Mushroom Cultivation: on shelves



mushroom cultivation on shelves

Cultivation steps

Once the production site has been prepared for mushroom cultivation and the plastic bags of spawn are in place on the shelves or the A-frame rack, the mushrooms can be cultivated. To stimulate mushroom growth, remove the cotton plugs from each of the plastic bags and water the outer surface of the bags and the mushroom house floor using a watering can. The bags of spawn should not be opened completely; simply pull out the cotton plug.

Figure 29: Pulling Cotton Plugs

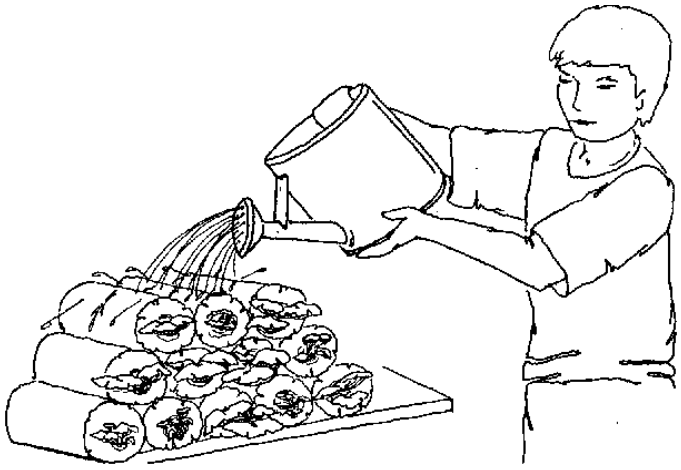
If the bags are opened fully, potential production is reduced due to decreased humidity next to the spawn and increased mushroom competition for a limited supply of food. Many mushrooms will try to grow at once, resulting in small, unmarketable produce.

Watering Method

It's not necessary to use great quantities of water when watering the inside of the mushroom house. It is necessary to water often; five or more times per day is not too often. Be careful to water only the outsides of the bags, never allowing

water to remain in the bags with the spawn. If water is allowed to sit in the bags, few, if any, mushrooms will emerge. Those that do emerge will rot before reaching maturity. Many people ask, "Why water the spawn at all? We only water the outsides of the bags, and it all runs off...the water doesn't even touch the spawn and if it does, the mushrooms die!" You need to water the inside of the house, and water often, in order to increase the relative humidity. By watering around and on the plastic bags, moisture is increased in the atmosphere nearest the spawn, where it is the most critical. The floor is watered in order to increase the supply of moisture in the house. Don't be afraid to water often. Two or three buckets of water five or six times a day is better than 10-15 buckets of water twice a day. Obviously, watering is very important during the dry season when ambient humidity is very low. It may be necessary to water the roof of mushroom house daily during the dry season.

Figure 30: Watering Plastic Bags

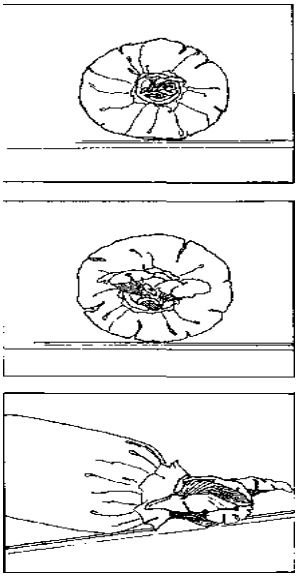


Harvesting

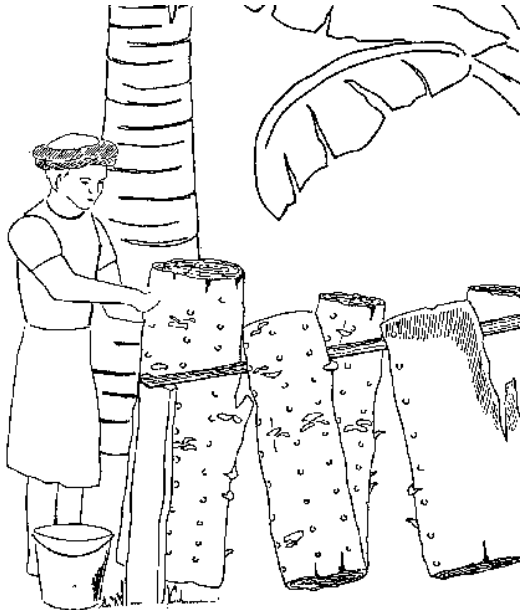
It will be possible to observe mushrooms growing within 3-4 days after removing the cotton plug from the bags of spawn. The first harvest should begin approximately seven days after the plug is removed, when the mushrooms are approximately 8-13 cm in diameter. To harvest, tear the mushroom away from the growing substrate at its base inside the plastic bag. After harvest, use a spoon handle or knife to scratch away 0.5-1.0 cm of substrate from the opening of the bag in order to expose fresh spawn to the humid conditions within the house and stimulate new mushroom growth. Another harvest will be possible in 8-14 days, at which time it will be necessary to scratch away more substrate. After 3-4 harvests, it may be desirable to cut an "X" in the back end of the bag in order to allow trapped spawn to develop into mushrooms. One bag of mushroom spawn will produce 200-500 grams of consumable mushrooms.

Like all mushrooms cultivated in Thailand, angel, oyster and abalone mushrooms grow best during the rainy season. As a result, supply is highest and prices (and profits) are lowest for these varieties during the rainy months. However, a farmer with a good mushroom house (i.e., one in which it is possible to maintain high relative humidity at all times) will be able to produce mushrooms with little difficulty during the dry season, and thus be able to capitalize on the high prices brought about by dwindling mushroom supplies, and realize a greater profit from his efforts.

Figure 31: Growth Progression



Harvesting

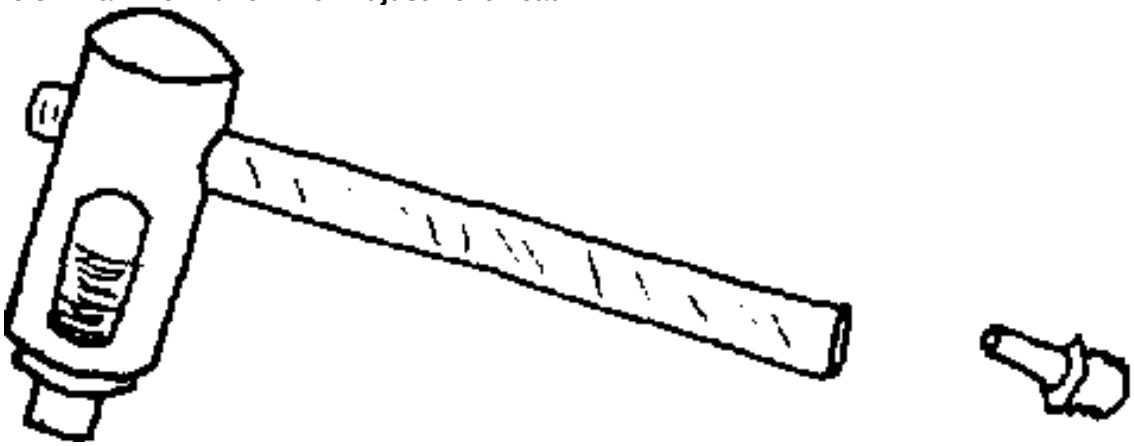


6. Wood ear mushroom cultivation in wooden logs

Materials needed

A hammer-punch or drill is needed to make the holes in the logs into which the spawn will be placed. The hammer-punch, as shown in Figure 32, is specifically designed to make the holes in wooden logs for wood ear mushroom cultivation. Hammer-punches are available at most outlets that sell wood ear mushroom spawn. While it is expensive--one hammer costs approximately B130-150 it is very easy to use, takes much of the work out of hole making, and can be used. for many years. It is not necessary for each farmer to have a hammer-punch; one can be purchased and kept at a farmer's house or at an agriculture extension office for many farmers to use as needed. However, if you don't want to use a hammer-punch, a common drill (manual or electric) will work as well. All that is needed is any available device that will make holes in the logs.

Figure 32: Hammer-Punch with Adjustment Head



Cultivation site

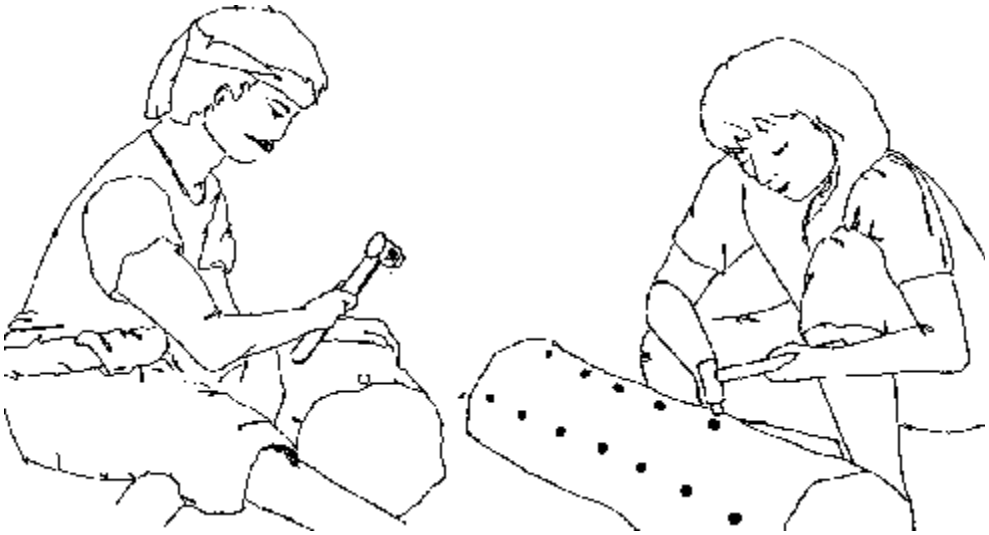
An appropriate site is also needed to cultivate the mushrooms in the logs. The mushroom house described in the section concerning cultivation of mushrooms in plastic bags is equally well-suited for logs. Growing wood ear mushrooms in a mushroom house will allow a farmer to extend the growing season and take advantage of higher prices during the dry season. However, if a farmer does not wish to build a mushroom house, the wood ear mushroom logs can be stored easily and cultivated under a tree, out of direct sunlight, during the rainy season. The naturally moist and humid conditions prevalent during the rainy season make this method of cultivation possible and profitable and reduces labor, since if it rains, the grower does not need to spend time watering the logs.

Wood ear mushroom spawn, unlike angel, oyster and abalone spawn, is not sensitive to prolonged contact with water. Hence, it can and should be exposed to rainfall; the more the better. Conversely, angel, oyster and abalone mushrooms are not grown profitably when exposed to heavy rainfall, i.e., when cultivated under a tree with no overhead shelter. As previously stated, angel, oyster and abalone mushrooms will rot before reaching maturity if exposed to prolonged contact with water. For obvious reasons, wood ear mushroom logs will not produce well, if at all, when cultivated under a tree during the dry season.

Cultivation steps

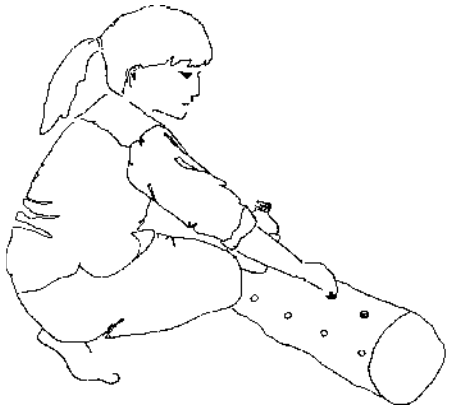
With all materials gathered, the planting of wood ear mushroom spawn can proceed. The first step is to punch or drill holes in the logs where spawn will be planted. The holes should be 1.3-2.5 cm deep (the hole should be punched or drilled through the bark and into the hardwood section of the log, see Figure 33) and 12-15 cm apart. Make the holes in lines or a zigzag pattern all around the log. It is not necessary to make holes in the ends of the logs.

Figure 33: Log Preparation for Planting Spawn



Once the holes have been made, fill each hole to the top with spawn. Do not press the spawn into the hole too tightly. Simply place the spawn in the hole and pack gently, making sure that the hole is completely full.

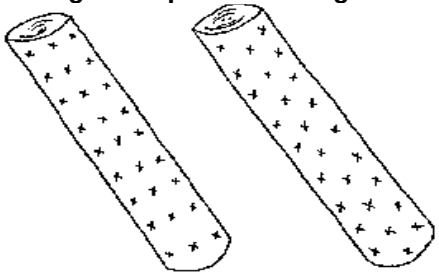
Figure 34: Planting Wood Ear Mushroom Spawn



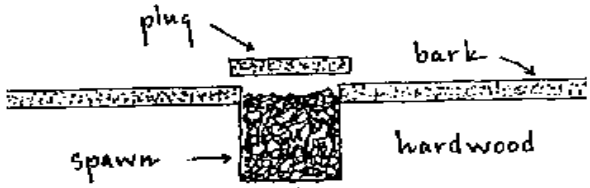
After placing spawn in the holes, seal the holes with bark, hardwood, plastic or wax plugs. If a hammer-punch is used, it will be possible to use bark or hardwood plugs as the hammer is sold with a removable head attachment designed to make cover plugs. Use a "trash log" to make the plugs, punching plugs out of the logs until it is impossible to punch anymore. Notice that the attachment makes plugs larger in diameter than the hole punched for spawn planting. This is to ensure a snug fit and to compensate for plug shrinkage as the wooden plug dries out. Hardwood plugs are usually better to use than bark plugs since the former tend to shrink less and are more likely to stay over the hole for a longer period of time.

To secure the plug in place, position the plug over the hole and strike the plug with a hammer or other hard object, driving it into the spawn-filled hole until the plug top is even with the surrounding bark. If a drill is used, and bark or hardwood plugs cannot be made, plastic plugs (available at most spawn outlets) or wax can be used to seal the hole. Plastic plugs are used in the same manner as bark or hardwood plugs and work well, but must be purchased, increasing total input costs. Wax also works well as a plug and can be purchased cheaply at most village temples. To use wax as a plug, first melt the wax, then allow it to cool before applying to the log. Hot wax should not be applied to the log as it will kill the mushroom spawn. While the wax is still soft, seal the holes, filling each with wax to the level of the surrounding bark.

Figure 35: Placement of Holes in Logs for Spawn Planting[2]



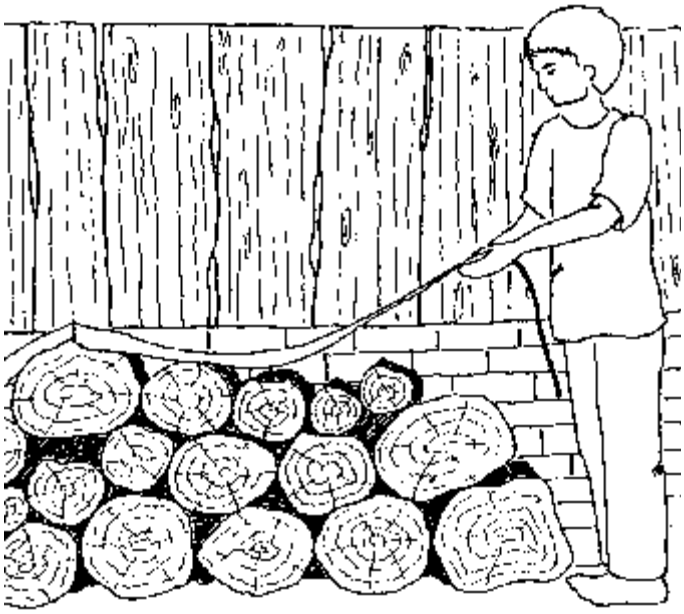
hole placement using line and zig-zag patterns



cross section of a log

[2] Adapted from Deeprom Chaiwongkeit, p. 76.

Figure 36: Storing Logs During Incubation



Incubation of Logs

After the spawn has been placed in the holes and the holes sealed, the logs are ready to be incubated for approximately three weeks. It is important to incubate the logs in a place where the logs won't come in contact with direct sunlight, wind, or moisture. If exposed to sunlight or wind, the logs will dry too quickly, causing the spawn to die before spreading throughout the interior of the log. If exposed to moisture, the spawn will exert its energy to produce mushrooms rather than spreading to the interior of the log to produce more spawn. As a result, overall mushroom production would be very small and short-lived. Consequently, do not water the logs until the Incubation period is over.

The desired sequence of events is for the logs to dry slowly, with the spawn following the remaining moisture to the core of the log. The log will then be filled with dormant mushroom spawn by the end of the Incubation period. As mentioned before, the incubation period for 20 cm diameter log is approximately three weeks. Smaller diameter logs require a slightly shorter Incubation period, larger logs slightly longer.

Placement and Watering of Logs

After incubation, the logs are ready to be moved to the site of cultivation. The most common way to store logs for cultivation, and the method that makes mushroom harvest the simplest, is to lean the logs against a bamboo or wooden pole which is secured parallel to and approximately 70 cm above ground level (the pole can be as long as desired) as shown in Figure 37. The logs should lean against both sides of the pole in order to reduce stress. Once in place, the logs are watered several times daily. (Note: Many growers of wood ear mushrooms advise soaking the logs in water overnight prior to moving them to the site of cultivation in order to help encourage rapid initial mushroom growth. This will not, however, increase the total mushroom production of the logs.) It is impossible to water the logs too much. Wet, rotting logs provide the best atmosphere for wood ear mushroom growth! Logs that are moist at all times will yield large quantities of mushrooms.

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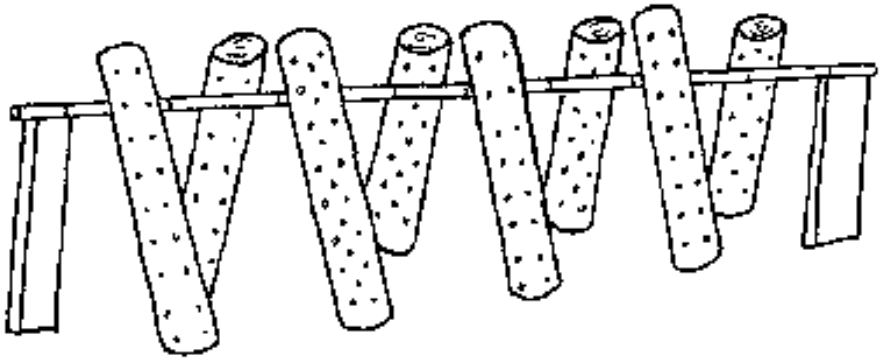
Figure 37: Storing Logs During Mushroom Cultivation



Harvesting

Mushrooms will begin to appear around the holes approximately 10-15 days after the onset of watering. The first harvest will be possible about 21-30 days after the first watering if the logs are kept moist at all times. Time from initial watering to first harvest is directly related to the diameter of the log. The larger the diameter of the log, the slower the emergence of the first mushrooms and longer the period of mushroom production.

Harvesting

To harvest, pull the mature mushrooms (those from 3-6 cm in diameter) from the log at their bases. Subsequent harvests will be possible every 6-8 days. Over time, mushrooms will begin to grow all over the logs, even on the ends, and will continue to grow until the log has completely rotted. A 20-30 cm diameter log will produce mushrooms for about 5-10 months, depending on diameter, growing conditions and the type of wood used. One 1520 cm diameter, 1 meter long log will yield about 1-2 kg of fresh wood ear mushrooms.

Figure 38: Harvesting Wood Ear Mushrooms

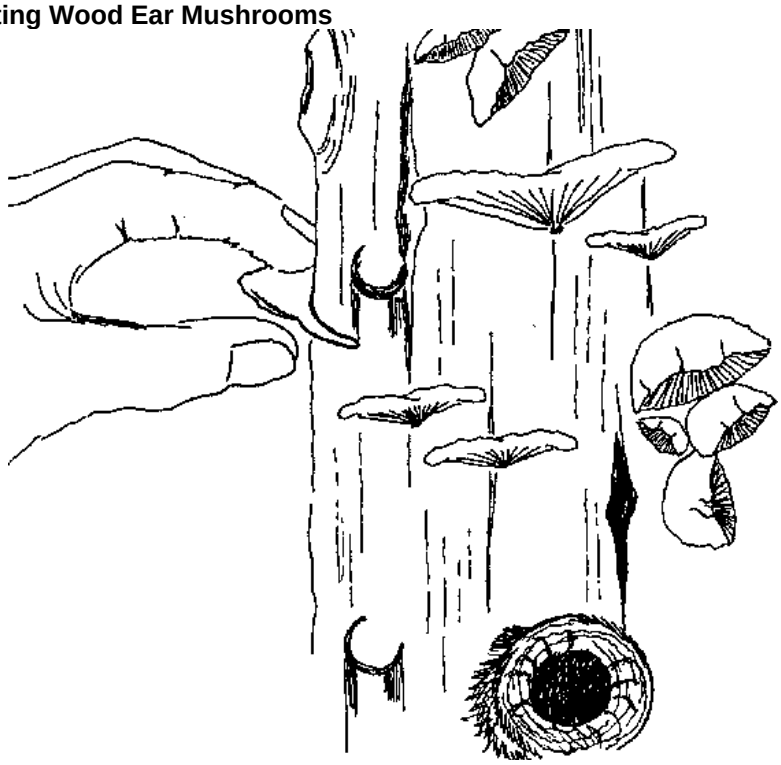
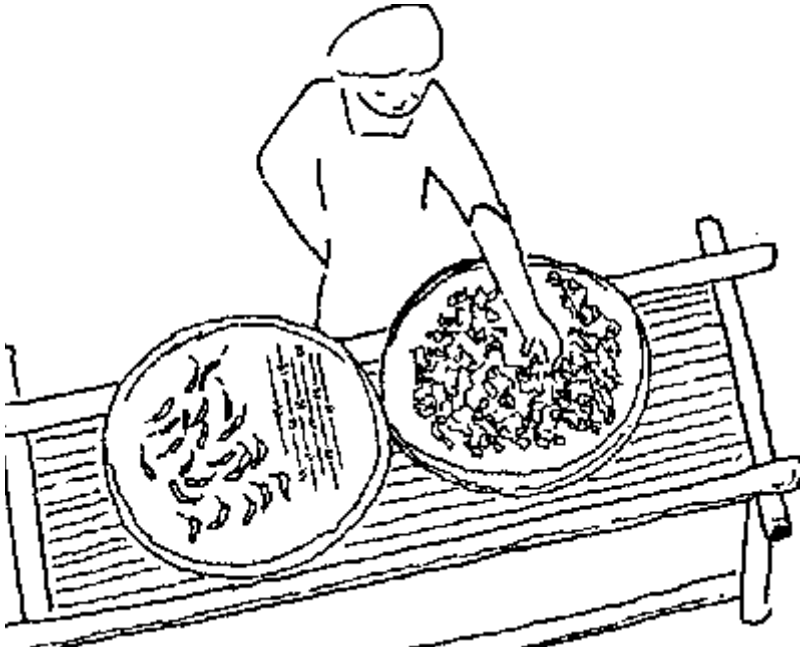


Figure 39: Drying Wood Ear Mushrooms



One major drawback

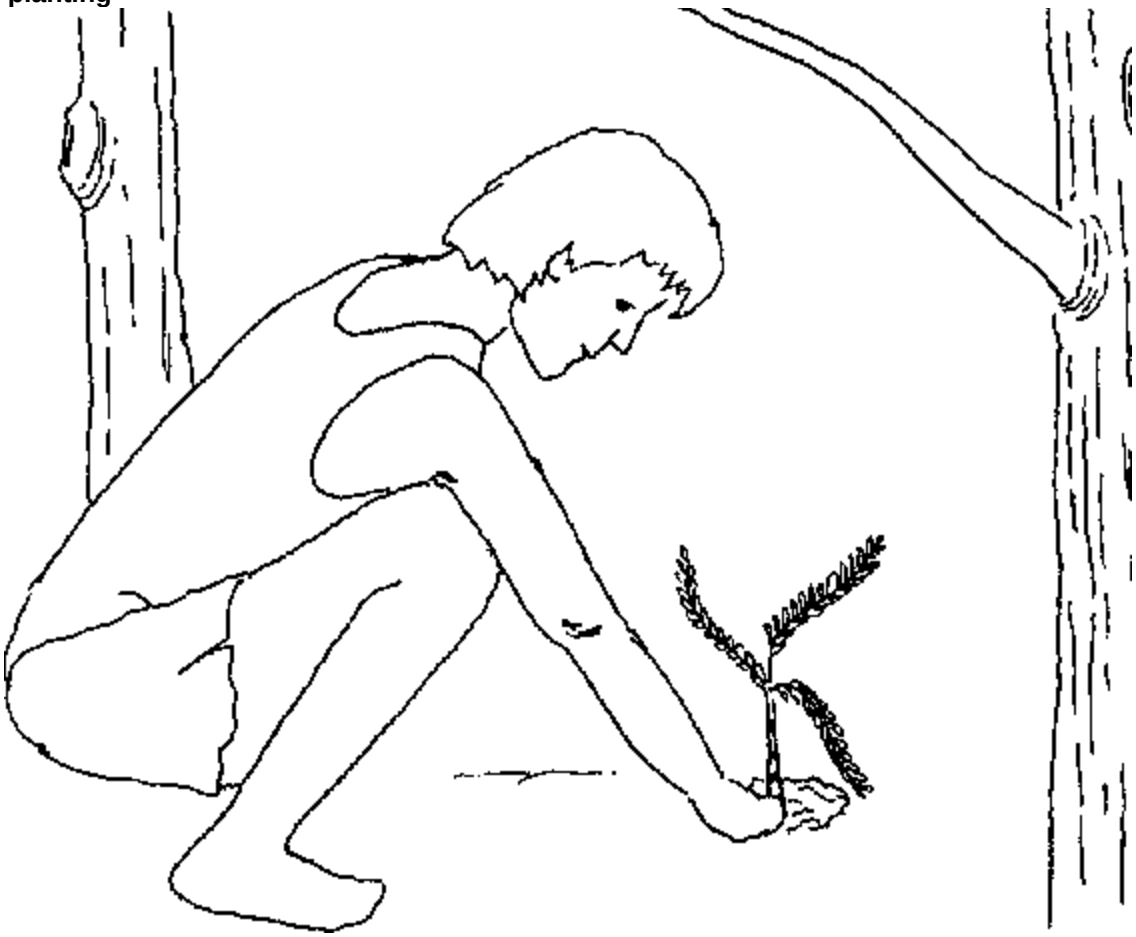
Wood ear mushrooms can be very profitable for a farmer to grow due to the low investment, high yield possibilities and high market price. However, wood ear mushroom cultivation does have one major drawback: cultivation requires the use of fresh wood as a growing substrate. Advising and encouraging farmers to grow wood ear mushrooms can accelerate local deforestation, already a serious problem

throughout Thailand. However, several steps can be taken to avoid deforesting the land and make wood ear mushroom cultivation possible almost anywhere in the country for many years to come.

Whole trees needn't be cut down in order to cultivate wood ear mushrooms; encourage farmers to trim their trees, and use the larger diameter limbs for mushroom cultivation. Trimming trees will also encourage rapid tree growth and high fruit or fiber production; it is a practice one should follow regardless of any desire to grow wood ear mushrooms. If farmers want to cultivate wood ear mushrooms on a large scale and cannot get enough tree limbs to use as a growing substrate, whole trees may need to be felled. If this must be done, encourage farmers to thin out their old, diseased or otherwise unproductive trees and use them for mushroom cultivation, leaving younger, stronger trees to grow to maturity and provide fruit or fiber for local consumption.

Finally, always encourage farmers to plant more trees than they cut. Many varieties of seedlings are available free of charge from government nurseries. Encourage and assist farmers in taking advantage of this service and plant trees! Some fast growing tree varieties (e.g., Katura, or) can be planted and harvested for mushroom cultivation after only 3-4 years of growth. Encourage tree planting! Using good foresight and proper extension techniques, any agricultural extension agent can make wood ear mushroom cultivation a profitable undertaking for any farmer without depreciating or destroying local resources.

Tree planting



7. Mushroom pests: prevention and eradication

Inevitably, farmers will encounter pest problems to one degree or another when cultivating mushrooms of any variety. If left unchecked, mushroom pests can cause great reductions in mushroom production. The

pests of greatest concern to mushroom growers in Thailand are molds, insects and mice. If cultivation is monitored closely, these pests can be eradicated easily before damaging the mushroom crop.

Molds

Molds are a common problem for mushrooms cultivated in plastic bags. The molds, usually green or black in color, are a result of temperature and humidity within the bag being higher than ambient conditions. Such molds are a common problem in plastic bags not yet opened for cultivation. Molds are usually first seen growing on the sorghum grain substrate near the plug end of the bag and, if left unchecked, moving down the sides of the bag completely covering and consuming the mushroom spawn.

To prevent molds from emerging, prior to cultivation store the plastic bags in a place free from excessive heat or high humidity. If molds do emerge, separate the mold-infected bags from the non-infected bags, and use a knife or spoon to scrape away the mold, being careful to scrape away 1-2 cm of growing substrate below the mold to be sure all of the mold has been removed. Discard the mold and substrate and cultivate the mushrooms as usual, keeping the infected bag away from non-infected bags to ensure that the mold, if it reemerges, will not infect other bags of spawn. Because it will be impossible to remove mold entirely from a bag of spawn, the mold may continue to emerge and few, if any mushrooms will grow. Hence, if the mold reemerges after one attempt at removal, the bag should be discarded and replaced with a non-infected one to ensure that the mold will not spread to other bags and reduce mushroom production.

Insects

Insects are another pest that can significantly affect mushroom production. Ants and termites are the two main insect pests of mushrooms in Thailand. They can cause problems for farmers growing mushrooms in plastic bags, logs and beds by eating the growing substrate and, in some cases, the spawn, greatly reducing potential mushroom production.

Insect problems are easily prevented by following good sanitation practices at the cultivation site. This is done by spreading lime on the ground at the site of production and/or spraying a mild pesticide (e.g., Malathion, Sevin-85, Pyrethrum) over the same area before beginning cultivation. If cultivating in a mushroom house, a 30-60 cm band of soil surrounding the outside of the house, as well as all the ground surface area within the house, should be limed and/or sprayed. This will kill all the insects that might be living in the soil and prevent others from entering from untreated areas.

Cultivation of mushrooms can begin one week after the initial treatment. Therefore, the perimeter around the house can be retreated every 15-30 days to ensure that insect pests cannot enter. (Note: Most people will not encounter any major insect problems while cultivating mushrooms. Therefore, it is best to grow mushrooms at the site at least once before engaging in a pesticide program in order to establish whether spraying is actually necessary. Do not encourage pesticide use by farmers with limited experience in growing mushrooms.)

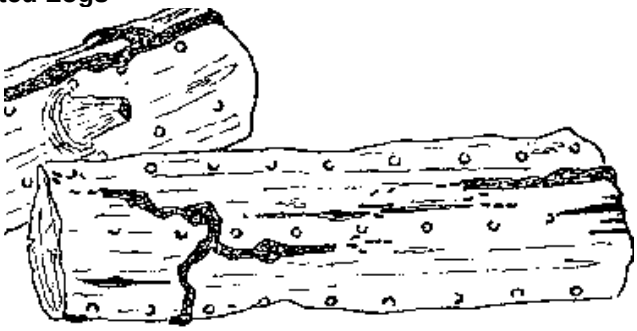
If insect pests have infested the production site extensively, they may cause great damage to the mushroom crop and should be eradicated. If the insects are infesting mushrooms being grown in plastic bags, all the mushrooms should be collected from the bags, then the outside of the bags should be sprayed with a very mild pesticide (e.g., Malathion, Sevin-85, Pyrethrum).

Be careful not to allow the pesticide to come in contact with the spore inside the bags! After all insects are eradicated or have left the area (usually in 1-2 days), water the bags generously with clean water in order to flush away any pesticide residue left on the bags. Wait 10-15 days before harvesting any mushrooms for consumption. Do not eat any mushrooms that may have emerged immediately following the pesticide application. (Note: Insect infestation will not usually warrant the use of pesticides. Use pesticides only in the most severe cases and be very careful in their application-especially with regard to mushroom harvest and consumption.)

Figure 40: Site Preparation: Spreading Lime

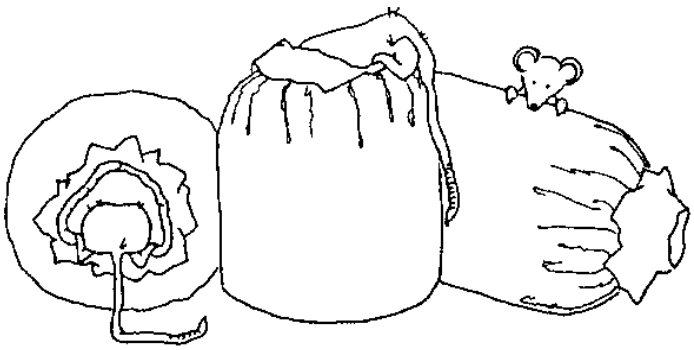
If insects are infesting logs where mushrooms are being grown, they can be eradicated by scraping the insects (most commonly termites) off the logs and then allowing the logs to dry in the sun for 2-3 days. Then completely submerge the logs in water for one or two days and resume normal cultivation of the mushrooms. Repeat this procedure as necessary. The longer insects are allowed to live on and feed off a log, the deeper they will tunnel into the log, and the harder they will be to eradicate. Therefore, spotting pests early, and quickly treating the problem is important.

Figure 41: Termite-Infested Logs



Insect infestation of straw mushroom cultivation sites is virtually impossible to avoid, let alone eradicate, due to the "open-ness" of the sites (as opposed to the "closed" environment of a mushroom house). As a general practice, farmers should change their site of cultivation after each harvest--from one rice paddy to the next (5-10 meters) is fine. If this is not possible, and insects are causing problems, the site should be cleared of all debris and limed and/or sprayed with a very mild pesticide to kill all pests in the area.

Mice



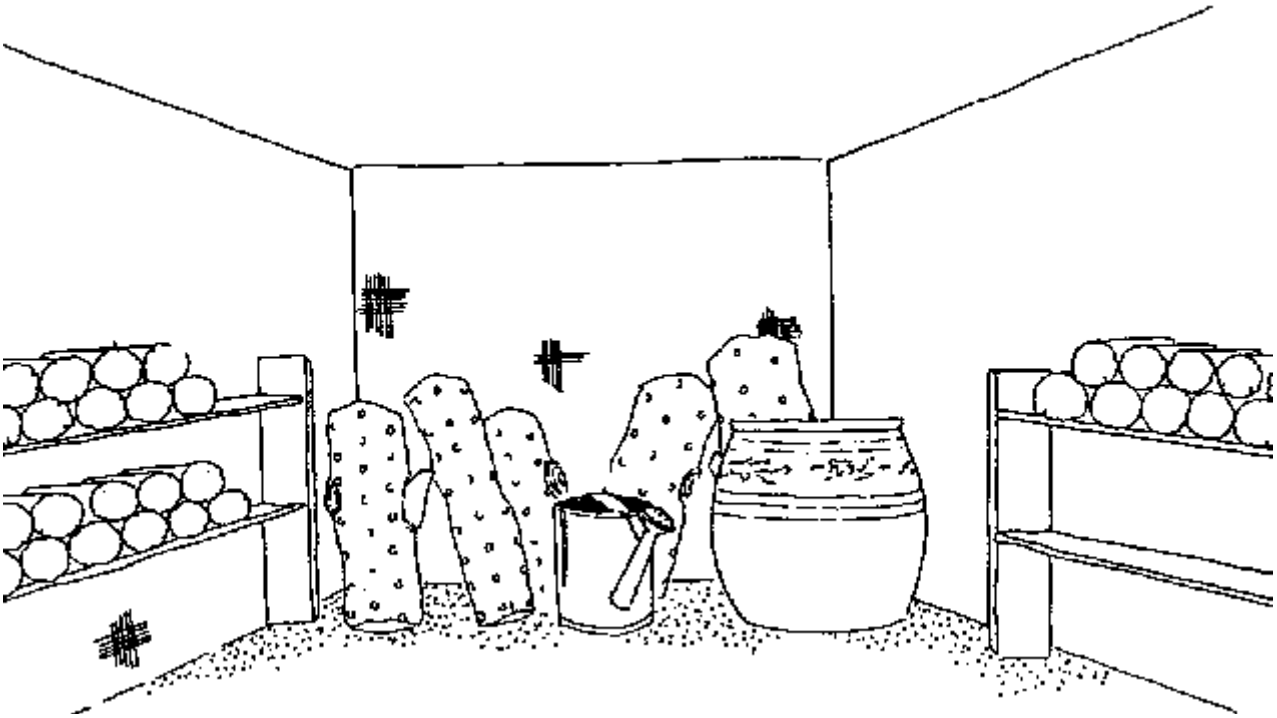
Mice

The final pest of major importance to Thai mushroom cultivators is mice. Mice are most commonly a problem when cultivating mushrooms in plastic bags as they will eat the grain in the bags and, in so doing, remove a great deal of growing substrate and mushroom spawn from the bags. Mice might also eat immature mushrooms growing in the bags or destroy them while searching for grain.

A potential problem with mice can be prevented by removing the grain substrate from the bags prior to beginning cultivation (this will have no effect on production) and by setting traps around the area of production. Poisons should not be used to kill mice as the mice might transfer the poison to the mushroom spawn, rendering the mushrooms inedible.

Although there are several possible pest problems facing Thai mushroom cultivators, any farmer following good sanitation and pest prevention practices will be able to cultivate mushrooms with little fear of reduced yields due to pest infestation.

Store



English word list

A

agar
age (v)
alcohol burner
ant
autoclave

B

bark
bed

C

calcium
carbonate
cheese
cloth
chop
compost
cotton
cover (n)
cover (v)
cultivate
cultivation
cut

D

drill (n)
drill (v)
dry (v)

E

equipment

G

grate (n)
grow

H

hammer-punch
hardwood
harvest, pick
hole
humidity

I

inoculating loop
inoculation
insecticide

K

kapok

L

layer
lean (v)
leucaena
lime
log
loose

M

magnesium sulfate
mice
mix
mold
mother spore
mushroom house
mycelium

N

neck, plastic tube

O

often
oil drum

P

pest (of mushroom)
plastic bag
plastic sheet
plug
poisonous
prevent
propagate
propagation hood
pull

R

rain
rice bran
rice straw
rot

S

sand
sawdust
scrape
separate, divide

shelves
soak
sorghum
spawn (n)
spread around
steam (v)
sterilization
store (v)
sunlight
supplementary food

T

temperature
termite

U

urea

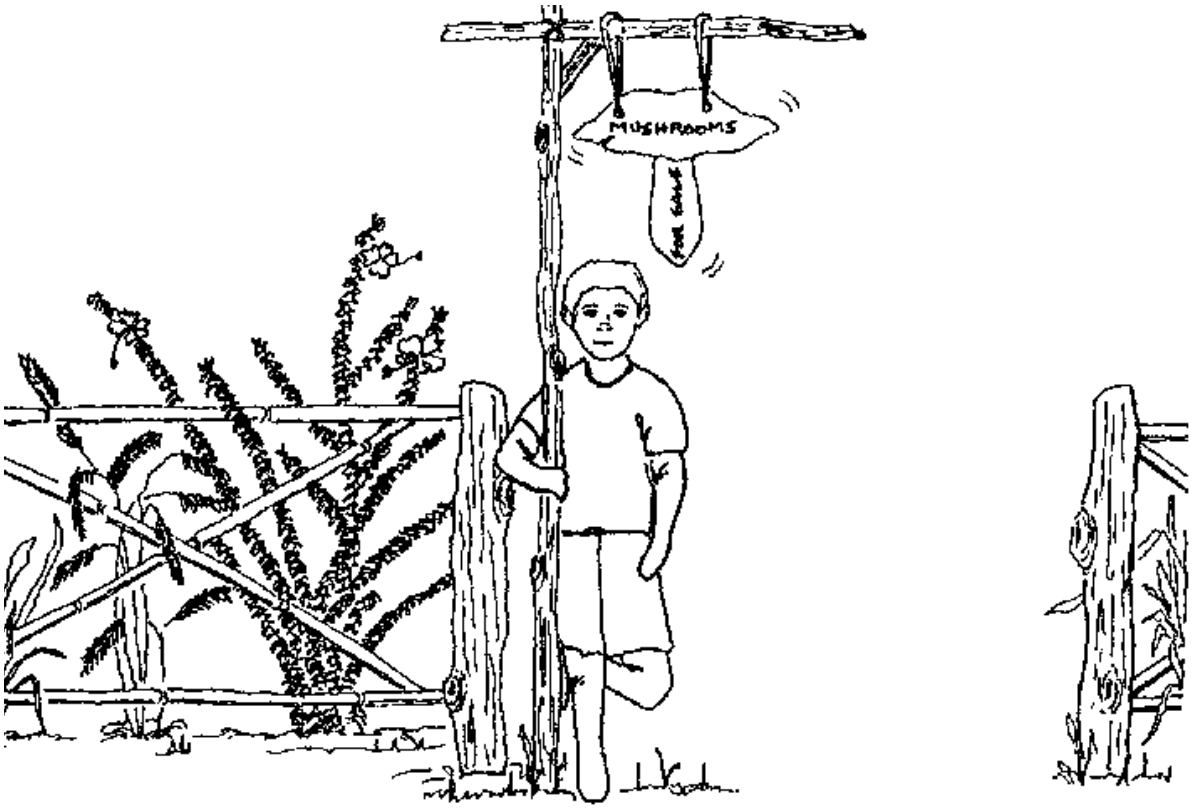
V

ventilate

W

water (v)
water hyacinth
watering can
wax
wet
wind
wooden mold

Mushrooms for sale



Appendices

Appendix A: Propagation hood: Use and construction

A propagation hood is an airtight box in which spore can be moved from one growing medium to another under aseptic conditions (i.e., free of all germs that may attack the pure mushroom culture). The hood should be thoroughly disinfected before each use (use bleach, methyl alcohol or formalin) so that conditions within the hood are truly aseptic. Likewise, all materials to be placed in the box during propagation activities should also be disinfected (i.e., bottles with PDA, alcohol burner, knife, inoculating loop).

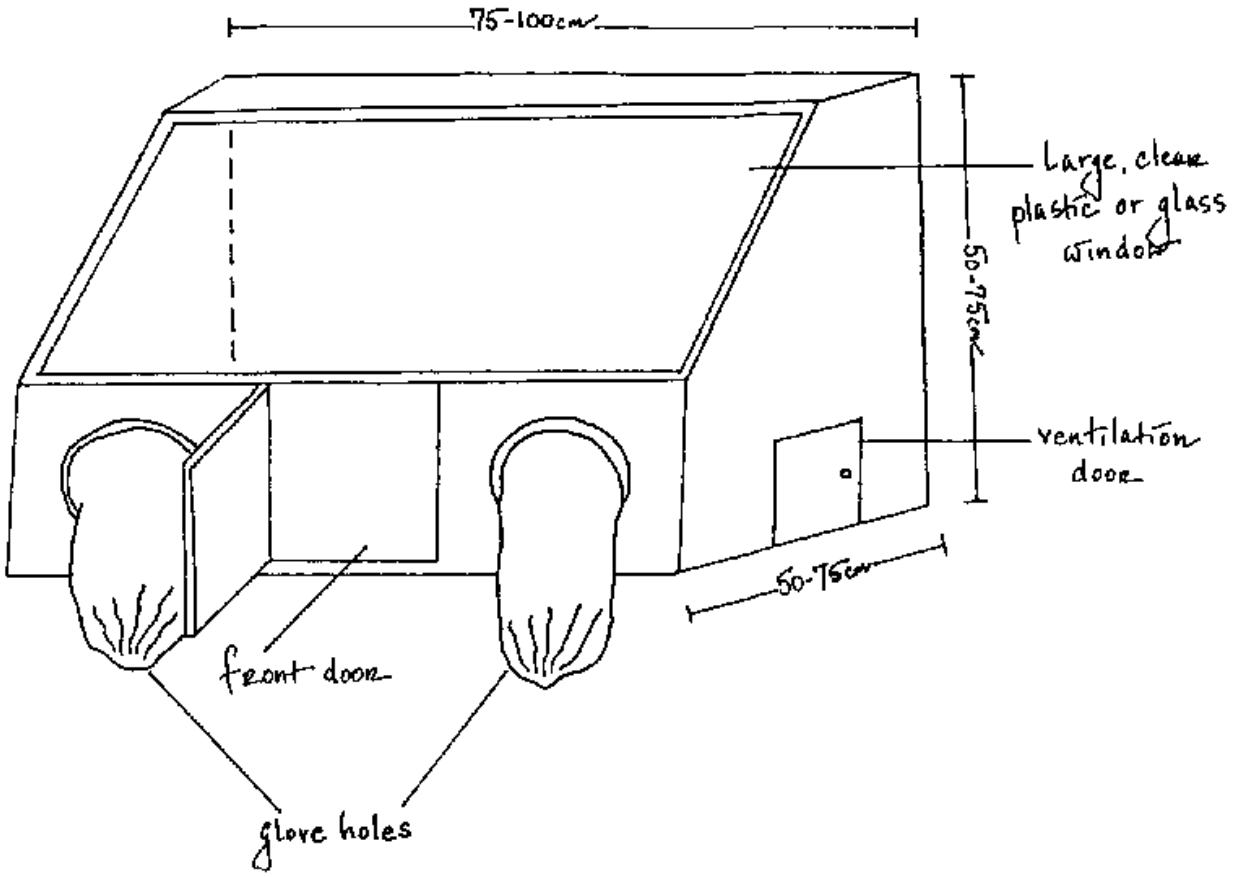
Propagation hoods are usually constructed of 1/4-1/2" thick plywood. Dimensions of a hood range from 75-100 cm in length, 50-75 cm in width and 50-75 cm in height.

A large, clear plastic or glass window is placed on the front of the hood at an angle to enable the propagator to view the work in progress.

The hood is equipped with two glove holes in which the hands of the propagator are placed when manipulating propagation equipment to prevent contamination of the boxes contents.

A ventilation door is located on the side or rear of the box. A front door is used to insert and remove propagation equipment.

Propagation Hood

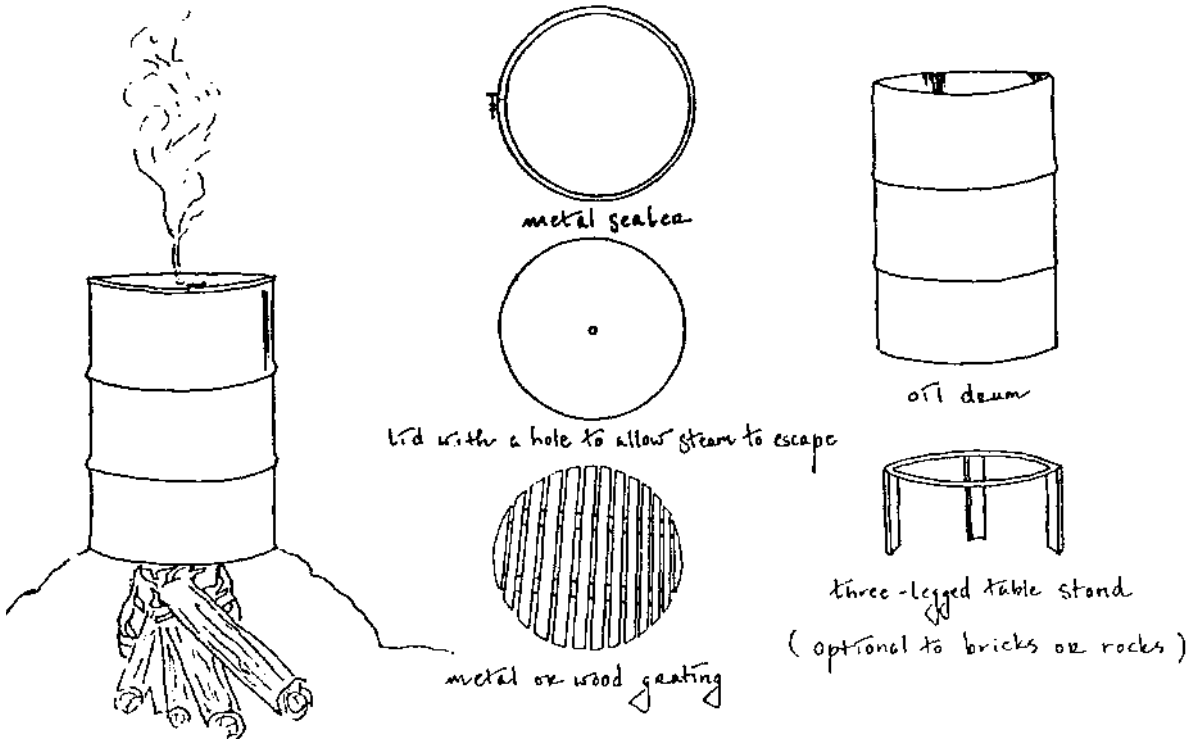


Appendix B.: Construction of oil drum autoclave

An oil drum autoclave is constructed using the following materials:

1. An oil drum.
2. Metal or wooden grate to be used to support the bags of spawn approximately 1 foot from the bottom of the oil drum.
3. Lid with hole, or holes, to allow steam to escape.
4. Metal seal used to tightly secure lid to the oil drum.
5. Heavy paper, cardboard or straw matting used to line the walls of the oil drum autoclave to ensure the plastic bags will not burn or melt during sterilization.
6. During use, the oil drum autoclave is supported by bricks, rocks, a metal stand or any other suitable material over a fire.

Oil-Drum Autoclave Construction Materials



Appendix C: Selected examples of growth media preparation: Angel, oyster and abalone mushrooms

1.

Rice straw (chopped 3-5 inches long)	100 kg
$CaCO_3$	2-3 kg
Urea (46-0-0)	5 kg
$MgSO_3$	2 kg
Rice bran	5 kg
Water (to moisten)	

Mix rice straw, calcium carbonate ($CaCO_3$), urea (46-0-0), magnesium sulfate ($MgSO_3$), and enough water to thoroughly moisten the resulting pile. The calcium carbonate, urea and magnesium sulfate may be combined in water before adding to the rice straw to facilitate the mixing process and ensure a good, even distribution of materials.

Turn the pile twice daily, mixing in rice bran on the seventh day. When the strong scent of ammonia generated by the pile has disappeared, and the pile no longer heats up after turning (generally around the seventh or eighth day), the mixture is ready for use.

This is enough compost to produce 150-200 bags of mushroom spawn.

2.

Rice straw (chopped 1-3 inches long)	40-60 kg
Horse manure	20 liters
Corn flour	2-3 kg

Rice bran	2-3 kg
Gypsum	2-4 kg

Refer to mixing steps above.

This is enough compost to produce 75-100 bags of mushroom spawn.

3.

Rice straw (chopped 1-3 inches long)	100 kg
Double super phosphate	1-2 kg
Ammonia sulphate	1 kg
Gypsum	1-2 kg
Corn flour	3 kg
Rice bran	3 kg

Refer to mixing steps above.

This is enough compost to produce 150-200 bags of mushroom spawn.

4.

Para rubber tree pulp	120 kg
Lime	1 kg
$MgSO_3$	3 soup spoons
Rice bran	5 kg
Water (to moisten)	

Place pulp in a pile and spread lime on top--do not mix in! Let sit for two to three days. This will eliminate mold spore in the pile.

Remove all large pieces using a sieve. Sieve the amount that you plan to use immediately.

Add rice bran and lime. Mix thoroughly.

Mix $MgSO_3$ and water, sprinkle on pile. Mix well. Make pile moist but not wet.

Let sit for 1-2 hours, allowing pulp to soak up water.

Place pulp mix into bags. Each bag should weigh approximately 1.2 kg.

This is enough compost to produce 150-200 bags of mushroom spawn.

From: Mushroom Culture in Thailand. Deeprom Chaiwongkeit. 1985. pp. 104-105.

Appendix D: Selected examples of growth media preparation: Wood ear mushrooms

1.

Para rubber tree pulp	120 kg
Lime	1 kg
$MgSO_3$	3 soup spoons
Rice bran	5 kg

Water (to moisten)	

Place pulp in a pile and spread lime on top--do not mix in! Let sit for two to three days. This will eliminate all mold spore in the pile.

Remove all large pieces using a sieve. Sieve the amount that you plan to use immediately.

Add rice bran and lime.

Mix $MgSO_3$ and water, sprinkle on pile. Mix well. Make pile moist but not wet.

Let sit for 1-2 hours, allowing pulp to soak up water.

Place pulp mix into bags. Each bag should weigh approximately 1.2 kg.

This is enough compost to produce 150-200 bags of mushroom spawn.

2. Pulp from other tree species may be used in place of para rubber tree pulp. For example, Durian, Kapok, Jackfruit and Mango are also good. When using pulp of other tree varieties, the procedure for use is the same as outlined above.

Appendix E: Selected examples of growth media preparation: Straw mushrooms

1.

Dried water hyacinth	10 kg
Leucaena leaves	1-3 kg
Water	10-15 liters

Gather 10 kg of dried water hyacinth and 1-3 kg of dried leucaena leaves, chop into small (approximately 1 cm long) pieces and mix together. Add 10-15 liters of water and mix well.

2.

Horse manure	10 kg
Kapok	1-2 fertilizer bags
Lotus seeds	8 kg

Water the kapok until moist and mix with horse manure. Compost for two days, turning the pile daily.

During this time soak the lotus seeds in water. On the third day, add the seeds to the horse manure/kapok mixture. Mix well. Let sit overnight. Mix once more prior to use.

Appendix F: Spawn purchase and handling

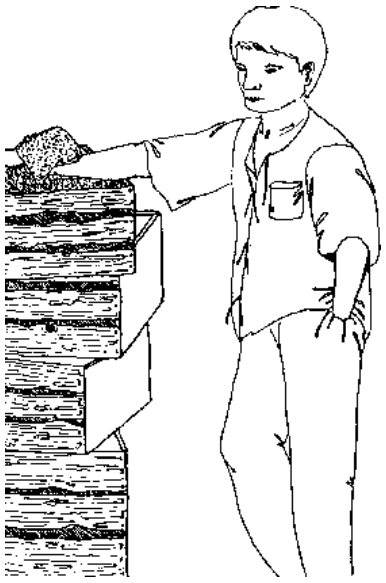
When purchasing spawn, be sure to observe the following criteria:

1. Choose spawn that is sweet smelling;
2. Free of any molds (usually of green or yellow color);
3. Not too old (mushrooms can be seen growing in the bag), or too young (mycelium growth is not yet evident), and;
4. Contained in bags that are undamaged (i.e., not torn or ripped).

When handling spawn, be sure to observe the following criteria:

1. Do not expose spawn to high temperature or humidity prior to cultivation as this will kill the spawn or lead to the introduction of molds in the bag.
2. Spawn should be kept out of direct sunlight.
3. Spawn should be protected from pests.
4. Spawn should be used shortly after purchase.
5. If planting will not be done until much later, the spawn purchased should be immature spawn and given time to develop in a cool dark place.

Figure



Appendix G: Nutritional content

								VITAMINS			
	Moisture	**Protein**	**Fat**	**Calories**	**CHO**	**Fe**	**A**	**B1**	**B2**	**Niacin**	**C**
Species	**(g)**	**(g)**	**(g)**	**(units)**	**(g)**	**(mg)**	**(I.U.)**	**(mg)**	**(mg)**	**(mg)**	**(mg)**
STRAW	90.10	2.10	1.00	34.00	4.90	1.70	-	0.12	0.33	9.10	2.00
WOOD EAR (Tender Variety)	87.10	1.00	0.10	42.00	10.90	6.10	-	0.02	0.11	0.20	-
WOOD EAR (Tough Variety)	78.20	1.10	0.20	76.00	19.80	6.80	-	0.03	0.09	0.10	-

From: Nutritional Content of Thai Foods, Kasetsart University, Bangkok.

Appendix H: Chart detailing important mushroom information

SPECIES	METHOD OF CULTIVATION	TIME PERIOD FROM PLANTING TO HARVEST	DURATION OF HARVEST	ENVIRONMENTAL REQUIREMENTS (a)	PESTS	YIELD	SEASONAL MARKET PRICE	
							High	**Low**
STRAW	bags, logs	10-20 days	1-2 weeks	T =35-37 C H = High L = Dark	ants termites	0.5-1.9 kg/bed (b)	rainy	cool
ANCEL ABALONE OYSTER	bags, logs	3-7 days	3-4 months	T = Cool H = High L = Indirect	molds mites	200-500 g/bag	cool hot	rain y
WOOD EAR	bags, logs	6-8 weeks	6-12 months	T = Cool H = High L = Indirect	termites molds	1-2 kgs/log (c) (600-700 g fresh = 100 (g) dried)	FRESH: cool DRIED: rainy	rain y cool

(a) From: Mushroom Culture in Thailand, Deeprom Chaiwongkeit. 1985.
(b) 1 bed = 80-120 cm long, 40 cm wide, 3 layers.
(c) 1 log = 15-20 cm diameter, 1 meter long.

T = Temperature
H = Humidity
L = Light

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