Chapter 1

PREPARING TO GROW MUSHROOMS: FACILITIES

The cultivation of mushrooms is an art, but it is based on science and technology. Any indevour, which is both an art and a science requires both study and experience. However, those who plan to grow mushrooms can be split into groups based on several factors. Maybe the most useful way to split them is to consider what they want to use:

1.Expertise – a person who has worked on a mushroom farm.
2.Waste materials he sees.
3.Waste materials from his own farm or other business.
4.A building he owns, or can get cheaply.

Most people would expect the first to be the most likely to succeed, but you may be surprised to learn that the entire list is in order of expected

success. Many waste materials work, but mixtures are generally better than any single waste. Most farmers who have wastes have other activities that they must pay attention to. So although they may be dedicated in spirit, they can not be completely dedicated to mushrooms. There are exceptions, but most buildings looking for a use, are not good places to grow mushrooms.

It is good to have wastes that mushrooms like to grow on, but there are plenty of wastes in almost every culture. The most important thing a mushroom grower needs is knowledge of how to grow mushrooms. Mushrooms are more like pigs and cattle than like wheat, or potatoes. Yet, like wheat and potatoes, everything they need must be available exactly where they are. However, it is not even that simple. Food for mushrooms is food for other things and mushrooms themselves are easy prey. Animals and plants both have skin that protects them. Mushrooms have little protection except that once established they are fierce competitors. The most important tool that the mushroom grower has is sanitation.

Even if the experienced individual needs help, discussing his needs will do little help others. More discussion of wastes will be useful, but we need to have a place to grow the mushrooms, or it will be difficult to do much. So let us begin by discussing buildings. The buildings are the physical protection for the mushrooms.

The reason most building looking for a use are a poor choice is because they do not provide the things the mushrooms need. It should be apparent that if most building are inadequate, mushrooms have special needs. How will we learn their special needs? One of the very best ways to learn the needs of living things is to observe the conditions where they grow normally.

THE NATURAL ECOLOGY OF MUSHROOMS

Oyster mushrooms are found wild in temperate forests and some species in tropical forests (**Fig. 1**). Typically, they grow on dead logs, one relatively uncommon species attacks weak living trees. We would, therefore, expect logs to be the best substrate, but we have found that straw and some other ligno-cellulosic wastes are better for cultivation. Forests are generally moist

Fig. 1. Oyster mushrooms (*Pleurotus*) in a natural, wild environment.

Fig. 2. *Agaricus* growing in the wild - grass.

places with dim light. Logs are sometimes buried by other forest debris. The survival of the species depends on the ability of mushrooms to protrude above the surface. Oyster mushrooms have evolved to use low carbon dioxide concentrations and light as indicators that they have reached above the surface. However, the trees filter out much of the light and blue light predominates, so mushrooms respond only to blue light. Many other wood inhabiting mushrooms have very similar needs.

Relatives of the common commercial mushroom are found in more open places and are associated with manure and already rotting debris (**Fig. 2**). While open places might suggest a need for light, we have found that *Agaricus* and other mushrooms associated with already rotting materials do not use light, but depend primarily on gravity as a signal to grow away from.

Carbon dioxide is also avoided. Wind is more likely to remove carbon dioxide in the open. Probably, it is also more likely to benefit from photosynthetic removal of carbon dioxide by grass and other small plants.

We can not get all answers necessary to describe the environment, simply from observations in the wild, but we can see that there are special requirments for envionments that we should be prepare to deal with in our buildings and in the other parts of our cultivation environment.

BUILDINGS AND OTHER FACILITIES

We have said that most ordinary buildings are not suitable for mushrooms. Oyster mushrooms have some basic requirements for the environment provided by the growing-buildings:

1.A temperature of 15 to 20°C (59 to 68°F)
2.A humidity of 80 to 95%
3.Good ventilation
4.Light
5.Sanitation

Temperature and humidity should be kept as constant as possible and the exact needs may depend on the variety. Any rapid changes in temperature will cause disastrous changes in humidity. At 20°C (68°F) and 90% humidity, if the temperature drops to 19°C (66°F) the humidity rises to 100%. If the temperature rises to 21°C (70°F) the humidity drops to 82%. At 15°C (59°F) the change will be approximately 1% less. That is 99% for 1°C loss and 83% for 1°C increase. The relation between temperature and humidity make insulation a must. Insulation may be a commercial material, but a thick layer of soil over a masonry building or straw or even paper between the inner and outer wall surfaces can be adequate.

At 100% humidity, everything is suddenly wet. Conversely, at 80% humidity, the mushrooms begin drying. If everything becomes wet, then many building materials will rot and others will corrode. So growing conditions

limit our choice of building materials. Concrete and plastic are two materials that will withstand considerable moisture with little damage. Some growers use wood or metal structures and cover them with plastic. Others just use wood or metal and accept its very limited life. The biggest problem with wood and some other porous materials is that they can harbor diseases and pests.

Both a good vapor barrier like polyethylene and insulation are needed to maintain temperature and humidity. In **Fig. 3** we see commercial insulation in plastic between the ribs (rafters) of a metal building. In Asia they have built houses of bamboo, polyethylene sheet and used straw for insulation (**Fig. 4**).

Good ventilation is needed for healthy mushrooms and for healthy workers. Low carbon dioxide is required for mushrooms to form. The stems *of Pleurotus* as well as other wood inhabiting mushrooms will grow until the carbon dioxide is very low. Centrifugal blowers are generally used to supply air. The air should be heated or cooled first and then humidity added before it enters the room. Of course, steam can humidify and heat at the same time. Ventilation must remove the carbon dioxide formed by the mushrooms, people and anything else. People can stand almost 10% carbon dioxide, but the mushrooms are more sensitive. Mushrooms should be picked before spores are shed, however, even with good management some spore will be released. Spores can cause asthmatic and hay fever reactions, ventilation can help reduce the spores in the air.

Light is required for oyster mushrooms and most other tree inhabiting species. One may read many things about the amount of light, but there have been very few carefully done experiments. I mentioned that forest light is blue. I have tried and failed to produce mushrooms with incandescent light. It is a rather yellow light. Fluorescent lights come in a variety of colors, The most common are “cool white.” With cool white if there is enough light to read and they are lit 8 hours each day you will have enough light. Natural daylight does not work well because the temperature will be affected by the sun. Algae and other plants are more likely to cause trouble in daylight.

Agaricus, the common commerial mushroom, does not require any

Fig. 3. Building with insulation covered by a plastic vapor barrier.

light and some of the older varieties change color with light. Generally the only light in the houses are battery operated lights on workers' helmets.

So, we generally do not want windows in any mushroom growing buildings. If light is needed by the mushrooms, fluorescent lights are generally the best light to use. If light is required only by people, battery operated lights are ususally the most satisfactory.

Sanitation is the most important thing that must be provided by the building. Sanitation will include:

1. Filtered air in
2. Screen or filters at air exits
3. "Air-lock" changing room
4. Foot bath
5. "Air tight"

ALL openings should provide some means to keep out diseases and pests. Air exits should have a fine mesh screen or a filter. Air inlets should be filtered to keep out pests and diseases. A High Efficiency Particulate Air (HEPA) filter is ideal, but other filters may be completely adequate. **Fig. 5**

Fig. 4. Growing buildings constructed of bamboo, polyethylene sheet and straw.

Top: Thailand

Bottom: Taiwan

shows two excellent furnace/air conditioner filters. If no commercial filters are available, three layer of muslin or similar fabric will be a good substitute. Screens or filters should also keep insects out of the air exits. Power failures and other problems may interrupt ventilation and insects will enter. They can even fly against the flow of air if it is not fast.

A room for workers to enter the growing facility can be built very cheaply with a light framework and black plastic film. It can contain rubber boots, a salt or hypochlorite foot bath and maybe clean clothes, masks or rubber gloves. The poorest possible source of light for mushrooms is sodium-vapor lamps. However, they are extremely efficient for outdoor lighting. While they are efficient for people. Insects can not see with them, so they are also

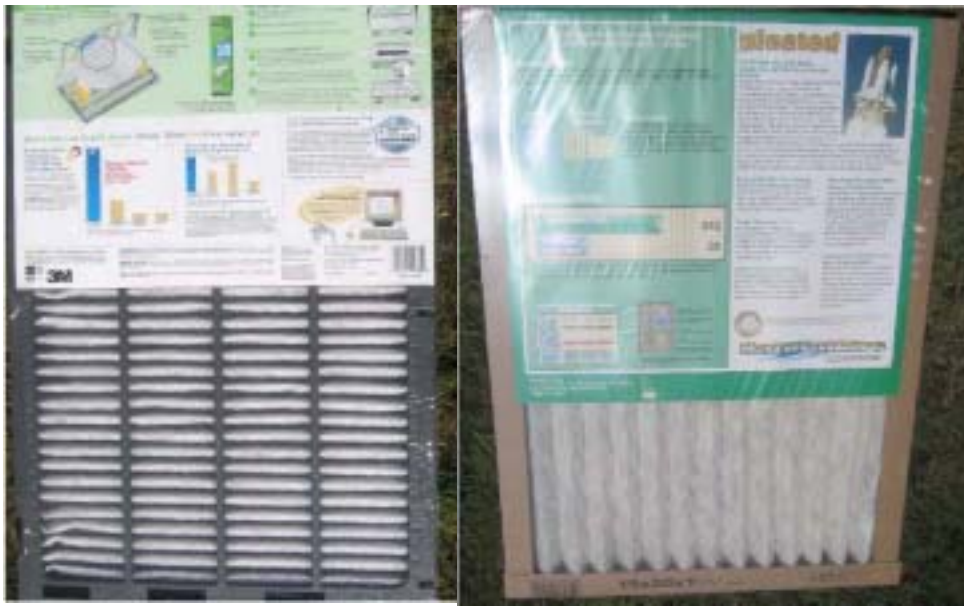

Fig. 5. Two high quality furnace/air conditioner filters.

good for "air-lock" changing rooms. Yellow colored incandescent light bulbs are also available, and are adequarte for humans, but are not seen by insects.

If the building can be made air tight, except of the controlled air inlets and exits, most diseases and insects can be kept out. Insulation foam, silicon or other caulk can be used to close small openings.

SUBSTRATE INITIAL PREPARATION AREA

Agaricus requires an area where substrate is wetted and ingredients mixed. That area is almost always outdoors although often there is a roof with no walls where front loaders and other machinery can do the heavy work. The area should always have a concrete surface that can be decontaminated, if it becomes a source of insects or disease.

Following mixing, the substrate must be composted. That may be done in the open, usually with heavy machinery to turn it. However, men with

Fig. 6. Right: A small hammer mill (open) showing hammers and "screen."

Below: Straw that was chopped by the hammer mill.

hayforks can do the job. Today most farms are using tunnels or "bunkers". These are indoor facilities where air is blown up throught the substrate as it ferments to compost. It is possible to add steam and pasteurize in the tunnels, as well.

Wood inhabiting species often use substrates which are more easily handled if they are first chopped in a hammer mill. Usually the best substrates are mixtures of several ingredients. The area should be dry, so a roof or more protection will be desirable for chopping and mixing.

In some cases, the substrate will remain dry until pasteurization takes place, in others it will be wetted before pasteurization. In still others it will be wetted and placed in the growing container as part of the preparation.

No mater how the substrate is handled after preliminary preparation, appropriate space must be available.

FINAL PREPARATION AREA

Pasturization requires equipment that can assure that the temperature of **ALL** the wet substrate is 55° to 60°C (131º to 140ºF) for at least 30 minutes. **IT MUST NEVER BE AT A HIGHER TEMPERATURE!** It must also provide conditions to protect the substrate from fresh contamination and allow it to cool slowly so that it is about 25°C (77ºF) after 16 to 20 hours.

Sterilization requires equipment that can assure that the temperature of ALL the wet substrate reaches 121°C (250ºF) for about 15 minutes. A pressure vessel is require to reach such temperatures. The substrate must be in containers the exclude the entrances of all microorganisms. Cooling must be slow enough so that there is little difference between atmospheric pressure and the steam or water vapor in the container of substrate.

Sterilization requires much more expensive equipment, much more fuel and much greater care at every step than pasteurization. It is almost universally recommended for some species that bring high prices. A few recommend it for *Pleurotus*. However, that suggests that they do not know proper pasteurization proceedure.

SPAWNING FACILITY

The place where the substrate is pasteurized, cooled, or sterilized must be maintained with greater sanitation than the growing area. It will probably be the best place to spawn as well. The air needs to be reasonable for those working there. But air temperature and humidity need not be controlled closely. It is ideal to have pasteurization or sterilization and spawning several kilometers from the growing area. Such an arrangement avoids many sources of disease and pests. The equipment at this facility is a substantial part of the whole. However, it will be discussed under the process because there is a choice of methods and equipment.

SUMMARY

Mushroom cultivation has many facilities requirements. There are no shortcuts to those requirements. If the requirements are not met, failure, or at least poor production is assured. The facilities must provide the environment required for mushroom growth. The facilities must also provide the primary protection against insects, other pests and disease. Without the environment and protection provided by the facilities, management can not protect the crop or obtain good yields.