

Part I Shiitake

Chapter 6

Shiitake Growing House

SHIITAKE GROWING HOUSES IN THAILAND
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Tropical Climate and Shiitake Growing

Thailand is located just slightly above the equator, and as such enjoys a tropical climate. Because shiitake prefers a temperate climate, it is mainly grown in northern Thailand and in the highlands of the northeast. Thailand has three seasons: winter (November-February), summer (March-May), and the rainy season (June-October). The average monthly temperatures and humidity for the last 30 years in northern Thailand are shown in Figure 1A and B. The highest daily temperatures are 39.0°C from March to June, with the highest being 41.4°C in April, so temperature control is essential for shiitake cultivation in summer. The temperature in winter is 10-20°C in nighttime and 20-30°C in daytime and is acceptable for fruiting initiation and development of shiitake with some management. Even in northern Thailand, the temperature and humidity are not suitable for shiitake growing in some months. Therefore, shiitake growing houses should be designed and managed to provide the proper environmental conditions for each stage of the mushroom's development during those periods of the year when the natural conditions are not appropriate for a particular development stage.

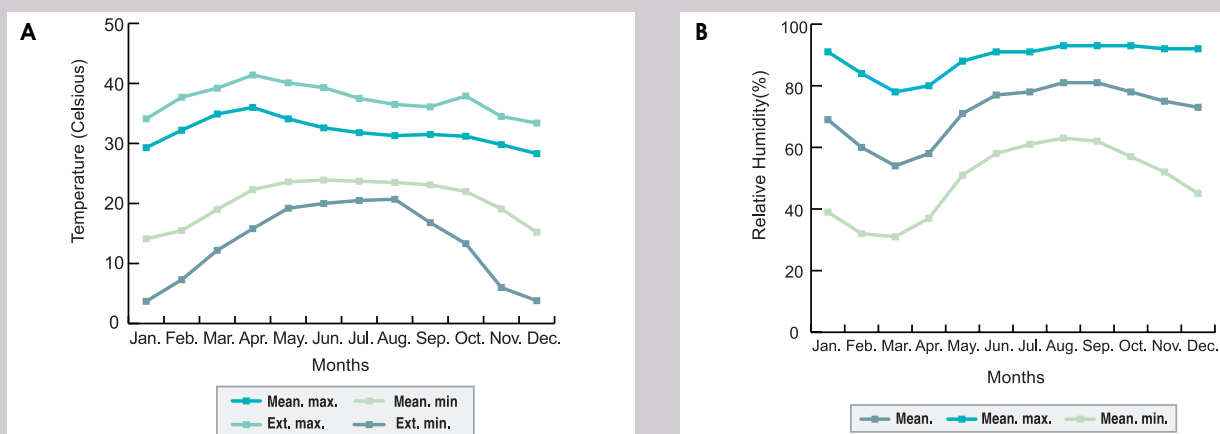


Figure 1. Climate in northern Thailand **A:** Average temperature of 30 years (1971-2000) **B:** Average relative humidity of 30 years (1971-2000) (Source: Northern Thailand Meteorological Centre)

Open System Shiitake Growing House

An open system is very popular for growing houses or sheds in Thailand. Under an open system, temperature, humidity

and ventilation are less controlled due to free flow of air between inside and outside of growing house. Although offering less control, the low cost required for construction and operation makes an open system very attractive. Most growers cultivate shiitake in the same growing house for the whole production cycle including spawn run and fruiting, by adjusting the environmental conditions such that they are appropriate for each stage of growth. Some shiitake farmers have two separate houses on their farms; one for spawn run and the other for fruiting. This two house method is much better because all of the required environmental conditions such as temperature, light, moisture, and air circulation are quite different for spawn run than they are for fruiting. Separate incubation and fruiting houses also allow farmers to cultivate several crops at the same time.



Figure 2. Typical shiitake growing houses in Thailand (C: Photo courtesy of Tawat Tapingkae)

Materials

Since shiitake prefer a temperate climate, the growing house must be constructed in such a manner as to protect the mushrooms from sunlight and heat in the tropical climate of Thailand. Materials for growing house is mostly selected according to local availability of materials and the budget which the farm can afford. Commonly used raw materials are trees, branches and leaves because these are inexpensive and easy to obtain. Of the many and various local leaves, the leaves of cogon grass (*Imperata cylindrica*) are the most popularly used for roofs and walls because they prevent heat accumulation due to the small air-spaces between the leaves (Figs. 3). Growing house made by cogon grass usually lasts for 3 years. *Dipterocarpus tuberculatus* Roxb and nipa palm (*Nypa fruticans* Wurmb) leaves are also used by many growers. *Dipterocarpus tuberculatus* leaves are easy to obtain in northern Thailand and more durable, but they keep more heat inside the house than *Imperata cylindrica* leaves. The nipa palm (*Nypa fruticans* Wurmb) leaves are not easy to obtain in the northern Thailand though it lasts for 5 years (Figs. 4).



Figure 3. *Imperata cylindrica* used for growing house A: Wall B: Roof

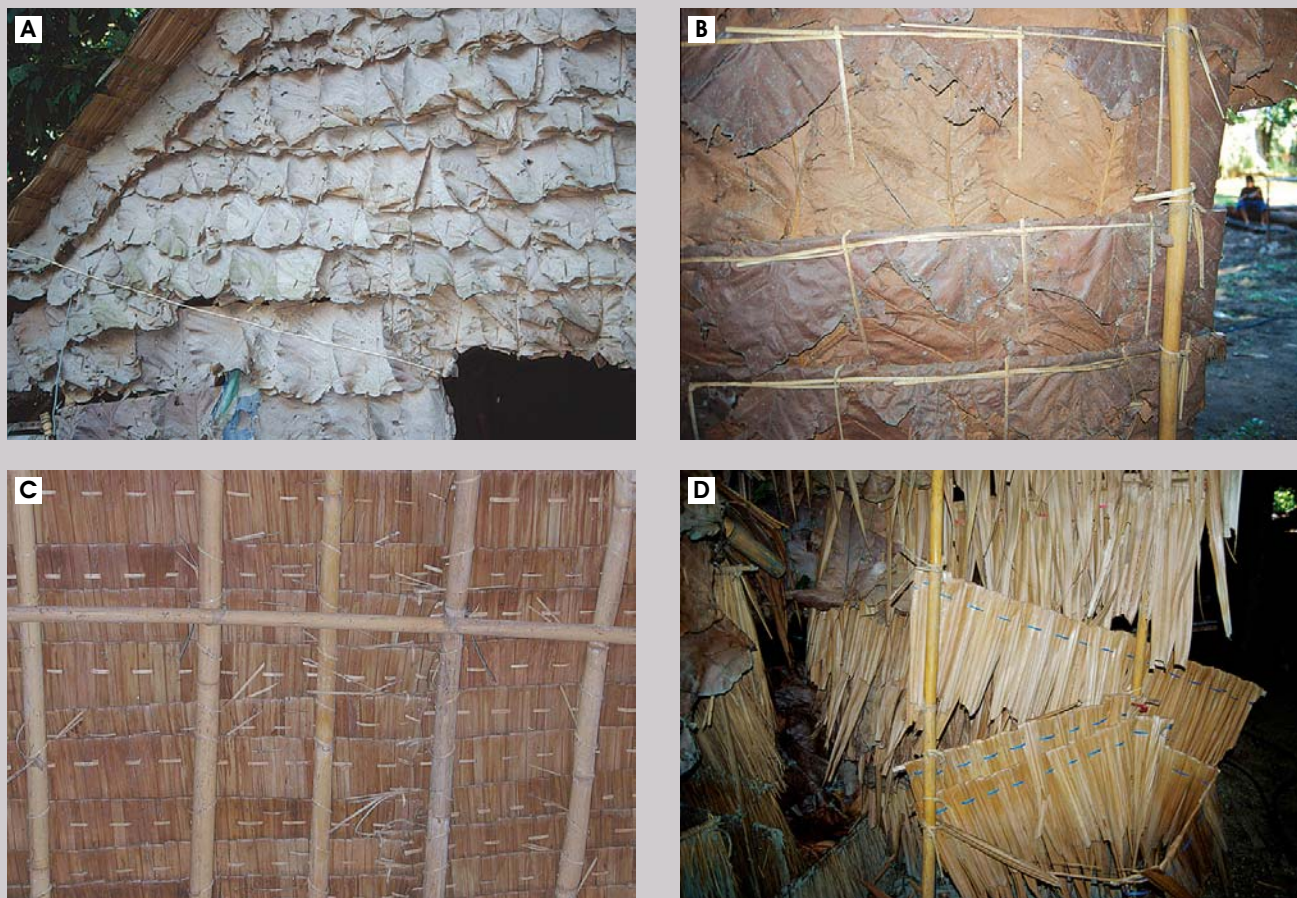


Figure 4. Various local leaves used for growing house **A** and **B**: *Dipterocarpus tuberculatus* Roxb **C**: Nipa palm (*Nypa fruticans* Wurmb) **D**: Layers made of nipa palm

Growing house design

The frame of an average Thai shiitake growing house is usually made with tree trunks and branches. The standard size of the floors is 10 × 22m, and five rows of shiitake bags are placed on it. The walls are 2m tall and shading net is used as the wall covering. Layers of leaves such as *Imperata cylindrica* cover the upper parts of the walls (Fig. 6). The shading net is rolled up or down to adjust the temperature, humidity and light. Growers are advised to cover the floor with thick layer of wet-sand bed in order to keep temperature lower and humidity higher inside the growing house (Fig. 5A). After watering the floor, the sand will maintain a higher humidity than either a concrete or soil floor can and evaporation from the sand will lower down temperature by 5-7℃. However, this effect cannot reach above one foot from the floor, so one layer of the bags is spread on the floor for fruiting stages requiring low temperature and high humidity. The specific construction details vary widely, and some shiitake farms do not use shading net, but use only local leaves as the wall materials (Fig. 5D).

The roof is an important part of a shiitake growing house, as it allows farmers to manage temperature and ventilation. Some growing houses have ventilation openings that promote air circulation by chimney effect (Fig. 5C). To prevent minute flies from entering through the opening, the fine plastic screen net or polyester fiber is applied. To optimize ventilation through the openings on the roof, it is recommended that the roof has a 5% slope toward the opening (Fig. 7). Hot air is inclined to move upward, so hot air right under the roof ascends again toward the opening. Hot air is therefore removed and cooler air pulled inside the house. Tall side walls of up to 3m are recommended in order to prevent the typical heat accumulation (Fig. 7).



Figure 5. Recommendations for better growing houses **A:** Floor covered with sand **B:** High roof to prevent heat accumulation **C:** Ventilation opening on the roof **D:** Wall made of only local leaves

Figure 6. Standard shiitake growing house

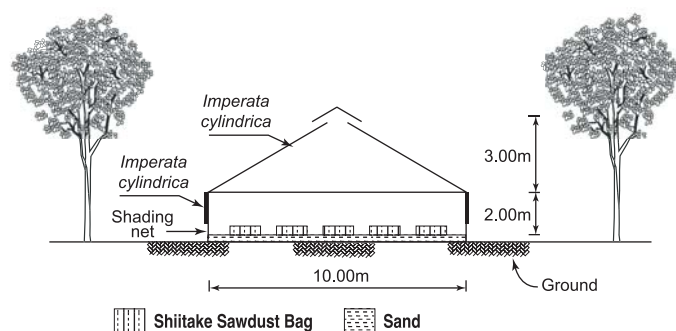
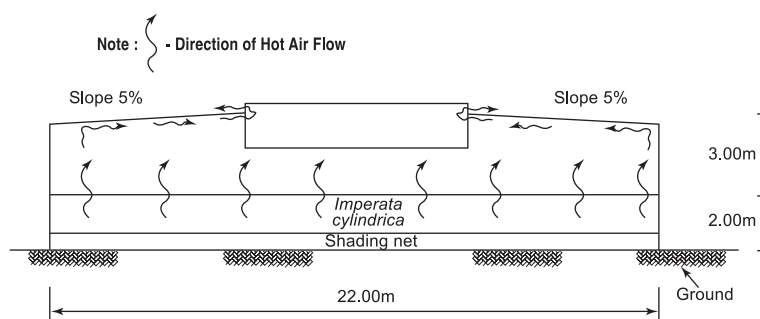


Figure 7. Side view of air flow in growing house



Characteristics of incubation house

Mycelial growth of shiitake requires a stable environment where the temperature is 24~26 °C and the relative humidity is 65%. If two separate houses are used, it is recommended that the incubation house be located under trees in order to lower daytime temperatures inside the house and narrow the temperature difference between day and night. The lower branches of trees do need to be trimmed in order not to obstruct the wind flow into the house. Shading net is usually used as the wall material to promote better air circulation. During the summers, a sprinkler system should be installed on the roof to lower the temperature inside the house by spraying water on the roof. The sawdust bags are placed either on the floor during spawn run or on a shelf in order to make full utilization of the space.

The spawn run period is very crucial for successful shiitake growing. Well incubated healthy shiitake mycelia usually indicate a capacity for high productivity and the fruiting stage then becomes much easier. However, keeping a steady temperature between 24~26 °C is not an easy task when using the open cultivation system. For this reason some large scale shiitake farmers create a controlled environment specifically for spawn run. Figure 8 shows such an incubation room named 'fan and pad cooling system' on a shiitake farm in Chiangmai in northern Thailand. The pad installed on one wall is wetted with water and the big fan on the opposite wall sucks out the air. The air gets more humidity by passing through the pad and the temperature is lowered and humidity is increased in the room as a result. This Pad-Fan system can lower temperature within the incubation room by 5-7 °C. An inside view through the fan is shown in Figure 8B in which shiitake bags incubating on the shelves are visible. The photographer was not allowed inside for fear of disrupting the environment.



Figure 8. Incubation room with controlled system **A:** Separated incubation room equipped with "fan and pad cooling system" **B:** Shiitake bags under spawn run on shelves (seen through a big fan on the wall)

Characteristics of fruiting house

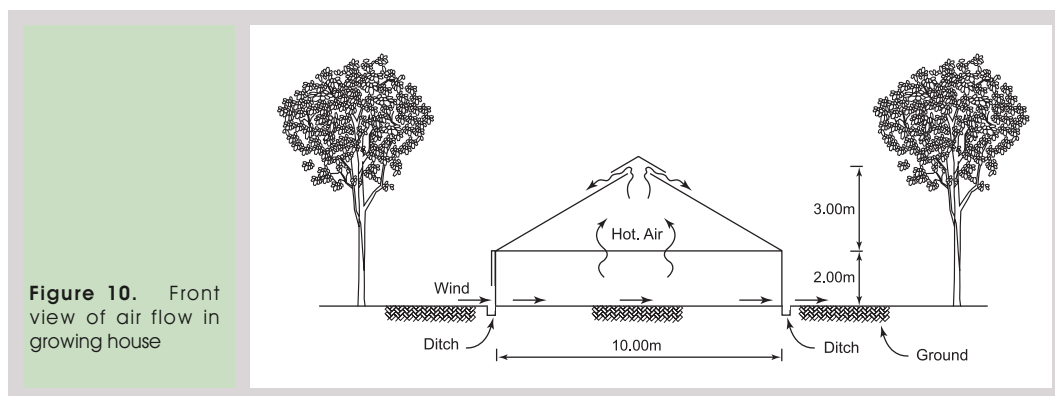
To induce fruiting of shiitake, the relative humidity should be maintained at 80-90% and temperatures allowed to fluctuate. If two separate houses are employed, the fruiting house should not be located in the shade, but instead in a sunny spot in order to make the temperature inside the house fluctuate between day and night because fruiting induction requires this fluctuation of temperature. A fruiting house is designed to allow for much ventilation to release inside heat and lower CO₂ levels. Fruiting houses are sometimes made with two roofs, while this is not done for incubation houses located in the shade.

The side wall is covered with shading net for air circulation and the upper part of side wall is covered with layers of *Imperata cylindrica* to keep humidity in the fruiting house (Fig. 9). The shiitake bags are usually put on the floor for fruiting, not on shelves. This is because water sprayed on the floor will cool bags on the floor, but bags on shelves cannot be cooled by such watering. This is an important consideration for shiitake cultivation, as shiitake does require lower temperatures than



Figure 9. Shiitake bags on the floor and ventilation through shading net

other mushrooms. The shading net is opened to keep moisture in or closed to protect from the drying mid-day winds. Sprinkler systems are installed on the roofs to reduce the temperatures inside during the day and to maintain a high humidity inside. Sprayed water is designed to flow down along the roof slope and the side wall into ditch in the ground. The wind can pass through the wet shading net walls and thereby lower temperatures and raise humidity levels (Fig. 10). This is modification of 'fan and pad cooling system' and requires much less investment than the system. Water will not drop on the bags as long as there are no leaks on the roof. Therefore, it is not necessary to make an inner roof of plastic if the natural roofing materials are well fashioned. There is also a ditch around the wall that allows water to flow and enter a storage pond. The water goes through a simple sand filter to remove dust and impurities in order that this material will not clog the sprinklers when the water is reused by the roof irrigation system (Fig. 11).



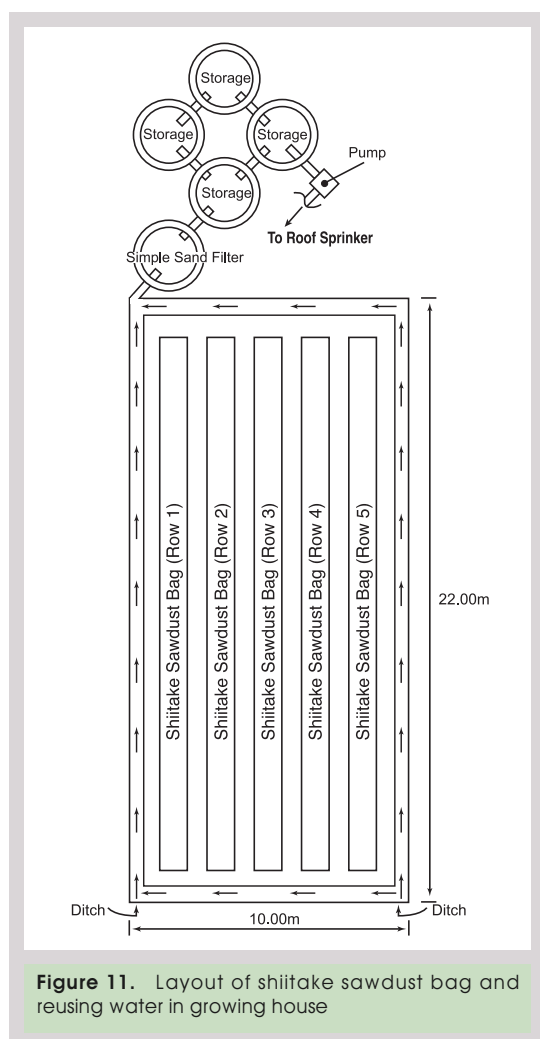
Sprinklers are also mounted inside the house to spray water on the shiitake bags for fruiting induction. If sprinklers are not available, water pipes or water containers can be used for sprinkling. Some growers use ice to cool down the bags, especially for the primordia induction before the first flush of mushrooms. Sprinkler systems equipped with timers are more efficient at lowering the temperature of sawdust bags because they can be programmed to spray a small amount of water periodically, which is very effective in summer for promoting temperature fluctuation and inducing fruiting.

Tips for Growing House Management

Management for spawn run

Temperature control

The temperature inside an incubation house needs to be controlled. In Thailand this means the temperature needs to be lowered. Various methods are used, such as watering, circulating air, and using natural materials. The shiitake mycelium requires a stable temperature of 25 °C for spawn run. Thailand's natural climate has a wide fluctuation of temperature between day and night, and this difference may reach 7.8-15.2 °C. During the daytime, growers are advised to spray water on the roofs, especially between noon and 3 pm. Any impediments to air circulation, such as trees, branches and leaves in the area, should be removed. The temperature can also be lowered by watering the outside of the house on the side from which wind is blowing. If the incubation house is under the shade of trees, the temperature inside will be lower than that outside by 3-4 °C. If all the mentioned methods are used, the temperature within an incubation house can be lowered to 32-33 °C from March to June when the outside environmental temperatures can be as high as 40 °C.



Pest control

Though local materials are cheap and easy to get, these raw materials alone are not able to protect shiitake from pests and disease. Therefore, growers are advised to spray insecticides, antiseptics, and disinfectants at least 5 days before placing sawdust bags in the incubation house. Another pest control method is to seal the house and its surrounding with plastic and disinfect the interior with a solution of formalin mixed with potassium permanganate. The main pests include snails that eat the paper lids, ants that sting the paper lid, and rats that eat inoculated spawn grain. Some farms control shiitake pests by mixing toxic sprays with pieces of papaya leaves to kill snails and ants, putting bait in rat traps, and by spreading lime on the floor to discourage snails and insects. Growers need to pay great attention to inspecting the shiitake bags in order to find any damage at its early stage. When a torn lid or a lid with a few holes in it is found, that lid should be changed immediately.

Light control

Shading net is generally used to make the building walls in order to control the light intensity. If a grower can see the shadow lines from shading net on their palm, the light is appropriate for spawn run. Starting in the fourth month after inoculation, the intensity of light inside the house is increased by opening the shading net.

Management for fruiting

Humidity control

The humidity should be maintained at 80-90% for fruiting induction and development. Much effort is required to keep the humidity high during fruiting induction. If there is no rain, the sprinkler on the roof must be turned on (Fig. 12). Sprayed



Figure 12. Sprinkler on the roof
(Photo courtesy of Tawat Tapingkae)

water then flows from the roof to the ground via the shading net, and air passing through the shading net creates humidity.

The floor inside the house should be regularly watered to allow the sand on the floor to maintain the accumulated humidity. From February to April, Thailand has a very low relative humidity, and is often below 65% when the temperature is as high as 40°C. In these conditions a fruiting house can become very dry. It is therefore essential to spray water mist on the roof and walls with a sprinkler, especially for the 2-3 days of fruiting induction. Once the shiitake has fruited, the relative humidity is lowered to 70% by spraying less water. The relative humidity within the house can be measured with an inexpensive wet-dry thermometer.

Temperature control

Thailand experiences a wide fluctuation of temperature between day and night during most seasons, and this is good for the fruiting induction. If more fluctuation is required, it is effective to lower nighttime temperature, especially from midnight to 5 a.m., by spraying water onto the sawdust bags periodically with timer controlled sprinklers. It is especially crucial to maintain the correct temperatures during the 2-3 days of fruiting induction.

Ventilation control

More oxygen is required for shiitake fruiting than mycelial growth. The shading net walls are opened to about 50cm above the floor to stimulate ventilation at night. On the other hand, the shading net is only slightly opened or fully closed at daytime because the outside relative humidity in winter and summer is very low and the outside temperature is higher due to watering in growing house. Dry and hot air from outside can cause a rapid change to the interior environment and this can cause poorly shaped caps on the shiitake. Whether to open or close the door depends on what the farmer feels about inside environment.

Pest control

Thai mushroom growing houses are quite susceptible to pests due to their open architecture and rustic construction materials. Regular control of pests is required. Insect catchers with glue on yellow sheets are very effective when attached 30cm above the shiitake bags. It is also effective to spray bio-substances such as *Bacillus subtilis* to control *Tricoderma* spp., and *Bacillus thuringiensis* to control worms. Fermented herbal juices like lemon grass juice or Galigate are effective for killing worms and insects. The fermented juice is easily prepared by chopping herbs into small pieces and then soaking them in alcohol for 1-3 days of fermentation. This juice can be preserved for long periods by keeping in an opaque container. Before being used, the juice is diluted with water in a 1:1000 ratio. Bio-substances should be sprayed every 7 days to destroy the insects in each cycle of life¹. Between the flushes the doors of a house are opened for ventilation in order to decrease diseases, most particularly green

mold disease. Toxic baits are also used and lime is spread for pest prevention in fruiting houses as it is also done inside incubation houses (Fig. 14).



Figure 13. Shading net is opened for much ventilation



Figure 14. Toxic baits for pest

Light control

Thai growing houses built with shading net and local leaves are easily adjusted to create the proper light intensity. Most of the roof and walls are weaved with many layers of local leaves, so some layers can be removed to allow in more light when more light is required for fruiting. The light intensity is appropriate for fruiting if it is bright enough to read a book inside the house. If the stems of the shiitake are too long, stem elongation can be slowed down by adding an illuminating light at night.



Figure 15. Light leaking into growing house



Figure 16. A layer made by cogon grass (*Imperata cylindrica*)

Experiences of Other Shiitake Growing Houses in Thailand

Roof materials

The roofs that are made from corrugated slate have the benefit of lasting for a lengthy period. These corrugated roofs also prevent rain and water leaks inside house that might drop onto the shiitake bags. However, this type of roof is too expensive, and it can both increase interior temperature. This type of roof also has difficulty in maintaining a high humidity inside the house, especially during the dry months from January to April. While the roofs made with local leaves such as *Imperata cylindrica* are good for temperature and humidity control, they are also easily damaged, and there exists a greater chance of water dropping on the shiitake bags inside.

¹ The shiitake pest usually has a long life cycle. For example, fly starts its life cycle as eggs and transforms into worm, pupa and then adult fly. According to the Pesticide Center in Chiangmai, Thailand, bio-substances are able to kill insect in any part of its life cycle. Moreover, insects including eggs, worms, and pupae are inside of the sawdust bags, so insecticide should be sprayed frequently for its high effect.

Various growing houses

Some growers construct shiitake growing houses with very thick walls in order to maintain humidity, but ventilation in these houses is hindered, and this leads to bags being easily contaminated by green mold or rot during the rainy season. In addition, in these thick walled houses it is very hard to lower the temperature for fruiting induction due to the lack of ventilation control. This problem is especially prevalent during the summer and causes a lowering of production. Some growing houses are quite large. In these cases fruiting is stimulated row by row, but air circulation problems restrict ventilation in the middle rows. Therefore, huge growing houses are not desirable. The proper size of a growing house is defined according to the conditions of the area, wind directions, and other concerns. Though the size of a house may be moderate, ventilation can still be blocked if too many houses are built near to each other or connected together.

Due to the hot and humid climate of Thailand, it is usually thought that shiitake are best cultivated in northern Thailand. Though not in the northern part, some other highlands are suitable for shiitake cultivation due to their low temperatures. If rivers or forests are near to the growing houses, high humidity from the forests can make the shiitake black and rotten. In this case, it is recommended that the growing house be wrapped to keep humidity from entering. But regardless, good ventilation is required to produce high quality shiitake.

Conclusion

Each growing house has a different environment, and differs in factors such as altitude, wind direction, topography, nearby vegetation, and other characteristics. All of these factors influence the unique micro-climate inside a growing house. Though the interior environment should be controlled for shiitake cultivation, there is not a single best practice for growing house construction and management that will fit for every season in every area. Each grower has his or her own techniques for the management of their growing house, and these techniques vary widely, particularly during fruiting induction. Certainly the biology of shiitake and the principles of its cultivation should be understood before any kind of cultivation management is undertaken.