Part I Shiitake

Chapter 6

Shiitake Growing House

SHIITAKE GROWING HOUSES-KOREAN CASES

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Climatic Environment and Growing House

Figure 1. Seasonal winds in Korea

Korea has four distinct seasons; spring, summer, autumn, and winter. Mountainous regions make up about 65% of the national territory. Although Korea has various regional climates, its general climate is affected by the Siberian air mass and the Northern Pacific air mass (Fig. 1). The Siberian air mass brings cold and dry winds from the northwest in winter while the Northern Pacific air mass brings hot and humid winds from the southeast during summer. Dry and warm spring weather sometimes sees the yellow sandy dust phenomena for several days due to the wind-blown loess from North China. The Okhotsk Sea air mass meets the Northern Pacific in late spring and early summer. Together these two air masses make a rain front on their contact surface, and this produces a rainy spell that lasts from late June to mid July. This rain front moves from south to north as the Northern Pacific high pressure gets stronger. This subtropical high then causes a hot and humid summer that starts in late July. Sometimes the equatorial air mass can cause typhoons during the summer.

The Korean climate affects the design and construction of their shiitake growing houses. In general, shiitake growing houses are more easily affected by the outside environment, in contrast to many other mushroom cultivation houses that are typically quite insulated from outside influences. Shiitake growing houses aligned in a north to south direction take advantage of the seasonal winds in winter and summer. Doors are closed in winter to exclude the cold and dry northwestern wind and the doors are opened in summer to take advantage of the humid southeastern wind. The north-south alignment of the growing houses exposes shiitake logs or bags to relatively uniform amounts of sunlight within the different parts of the growing houses. If the growing houses are built in an east-west alignment, because Korea is located in the northern hemisphere, the bags or logs in the southern parts of the growing houses would receive full sunlight, and as a result a temperature gap would occur between the northern and southern parts within the growing houses.

A good water drainage system is very important. In particular, the hot and humid summers experience 70% of the annual rainfall. Summer usually includes one solid rainy month, and quite a few typhoons. The center of a growing house floor is a bit raised and drainage canals surround the structure. Gravel on the floor is very helpful for water control as well. Korean summers are quite hot, and the temperature reaches 32℃, so shading nets are used to block the sun. The density of the shading nets varies from 50 to 100%. Air filtration is needed in spring due to the yellow sandy dust phenomena, and roofs and

walls must be cleaned by washing with water.

There are several kinds of shiitake growing houses in Korea, and they vary according to the extent of environmental control possible, cultivation methods, and the structure of the growing houses. Among them, ordinary growing house and overlapping open roof growing house will be examined. Detailed construction process and management for overlapping open roof one are also provided.

Ordinary Growing Houses

Log cultivation

Shiitake log cultivation does not require many environmental controls. Spawn run and fruiting induction can be done outdoors under trees in the forest. A simple structure is sufficient for screening direct sunlight and offering protection from rain and snow. Such minimal control is possible because the bark on the logs themselves provides good protection for the inoculated shiitake mycelia. However, the logs do require seasonal management. During the dry springs, the stacks of inoculated logs are protected under plastic covers to prevent excessive drying (Fig. 2A). Later, as the spawn run continues within the logs, the plastic covers are removed and shading nets are mounted to protect the logs from direct sunlight (Fig. 2B). Much attention is paid to preventing the logs from getting wet during the rainy spell and severe rainstorm of summers.

Figure 2. Log cultivation **A**: Logs covered with plastic sheet after inoculation **B**: Shading nets **C**: Logs in growing house

Sometimes, the logs are placed within a fully equipped growing house effective for sun screening and ventilation (Fig. 2C). Sometimes, watering nozzles are attached under the roof. Although this increased protection allows a higher productivity and quality, production costs also increase. Nonetheless, quite a few growers are now using these more expensive growing houses because the price gap between the lowest and the highest quality can often be a factor of 10 times and this allows growers to target much larger profits with only a slightly larger investment.

Bag cultivation

Bag cultivation requires a great deal of cares, so bags are cultivated exclusively in well controlled growing houses. The inoculated

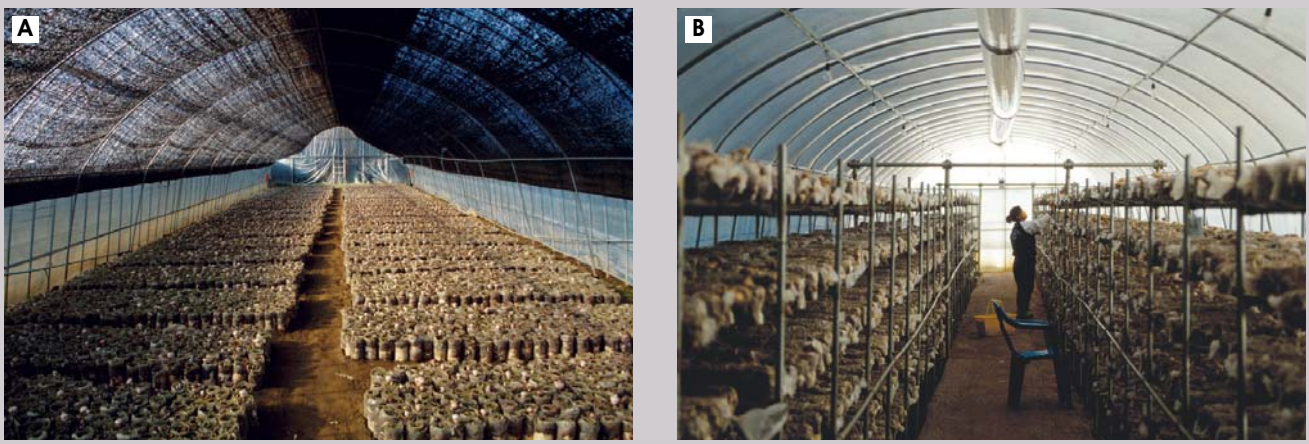

Figure 3. Bag cultivation in growing house **A**: Fruiting on the floor **B**: Fruiting on shelves

bags are colonized by shiitake mycelia in an incubation room or in the growing house. When the spawn run is complete, the bags are spread on the floor or on the shelves of a growing room (Figs. 3). Temperature and humidity is controlled mostly by ventilation and the side walls can be rolled up and down to control the environment inside the houses. (Fig. 3A).

Overlapping Open Roof Growing House

Shiitake prefer a temperate climate, so it is difficult to cultivate them during hot summers. The biggest problem for Korean shiitake growers is lowering the temperature in summer. The overlapping open roof house is a design that has been modified in order to allow growers to efficiently control the growing environment in the hot and humid Korean summers by promoting more ventilation through the open roofs. This house style is very effective and the construction cost is not much higher than a regular greenhouse. The basic structure permits growers to make use of the external environment rather than attempting to artificially control it. Warm air moves upward within the growing house, then it naturally goes out through the opening on the roof and the empty space is filled with outside air coming in through the open side walls or side wall shading nets. Though its arch roof is opened to outside air, the overlapping section protects the inner space from rain and snow (Fig. 4A). Cold wind and storms can be effectively blocked by covering the roof with a plastic cover. It is recommended that the open section face away from the direction of prevailing winds and storms. This type of growing house can be used both for log cultivation and bag cultivation and is available in every season, but is especially useful during hot summers.

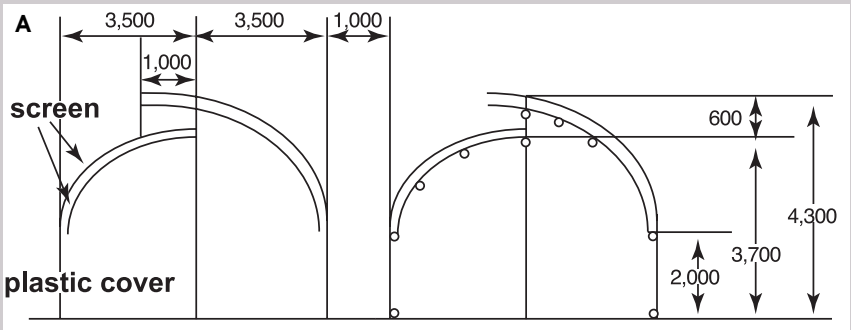

Figure 4. Overlapping open roof house **A**: A plan of overlapping open roof house **B**: The overlapping open roof seen from inside growing house

Construction model of an overlapping open roof growing house

Figure 5. Inner structure **A**: Inner structure of plastic film **B**: Windshield against cold wind in winter

This example is a threefold structure using an overlapping open roof house, and allows for more effective growing house management. This growing house consists of 1; the inner structure of plastic film, 2; the outer structure with an overlapping

open roof, and 3; the outside shading nets.

The inner structure consists of a simple construction and plastic cover of 0.1mm in thickness (Fig. 5A). The plastic cover of both the arch roof and the side walls can be rolled up and down by controlling winches. A plastic windshield covers the side wall from the bottom up to a height of 50cm in order to block the cold wind in winter (Fig. 5B). Cold air is heavier than warm air, so it is usually on the bottom, so this windshield is effective at preventing cold wind from coming into the growing house.

The outer structure has an overlapping open roof (Fig. 6A) that fully covers the inner structure. There is a space about 50cm wide between the inner and the outer structure. The outer structure is covered with two sheets of plastic that cover a sheet of cashmilon in the middle. White cashmilon maintains interior and is good for light transmission. The open roof can be closed with a winch.

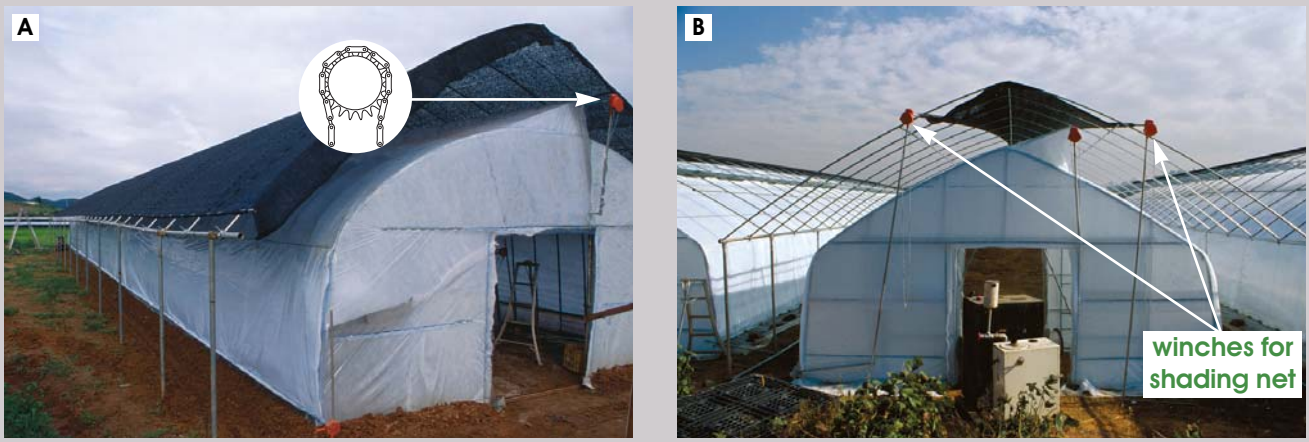

Figure 6. **A**: Outer structure and shading net **B**: Shading net rolled up

The outside shading net protects the growing house from direct sunlight. This particular structure does not have side walls or doors, but only has a roof with shading nets. The shading net can be rolled up and down by winch. (Figs. 6). The density of shading net varies from 50-100% and Figure 6A shows shading nets with a 90% density.

Construction step 1: making framework

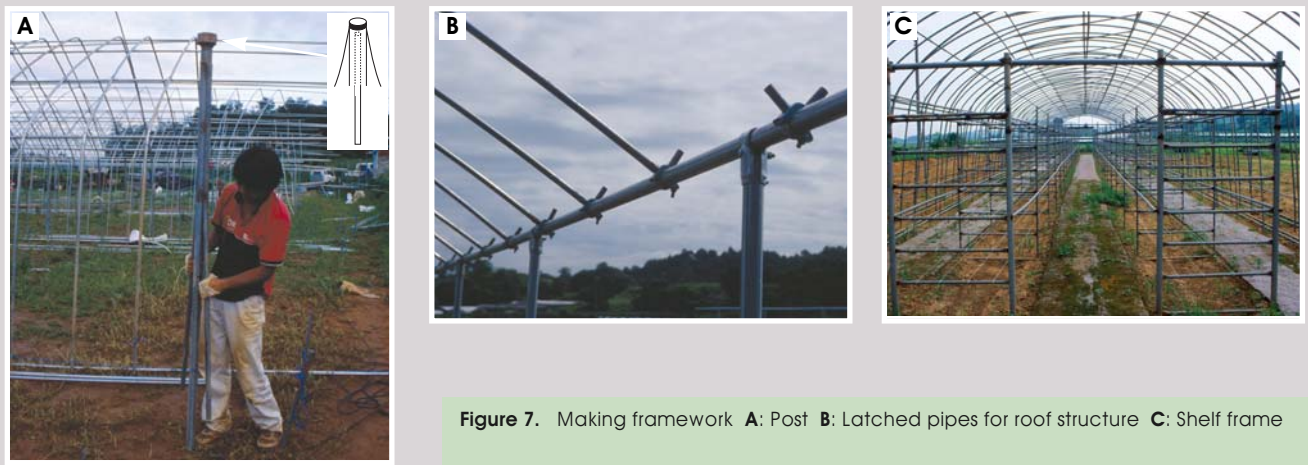

Figure 7. Making framework **A**: Post **B**: Latched pipes for roof structure **C**: Shelf frame

All the obstacles are removed on the selected location and the ground is leveled. The first work is to set up the posts of the side wall (Fig. 7A). Posts can be hammered into the ground with the tool shown in the circle (Fig. 7A). The roof pipes are bent to more than 30 degrees to prepare for heavy snowfall in winter. The high angle will prevent snow from accumulating on the roof. The roof pipes are connected with a pipe on the side wall posts (Fig. 7B). All the pipes for the framework are

tightly tied together. Frameworks are constructed for the inner structure, the outer structure, and then the shading net. When the frames are all completed, a shelf frame is also constructed inside the house if the house is to be used for bag cultivation (Fig. 7C). When the shelf frame is fixed, coated wire is arranged on each rack to support shiitake bags.

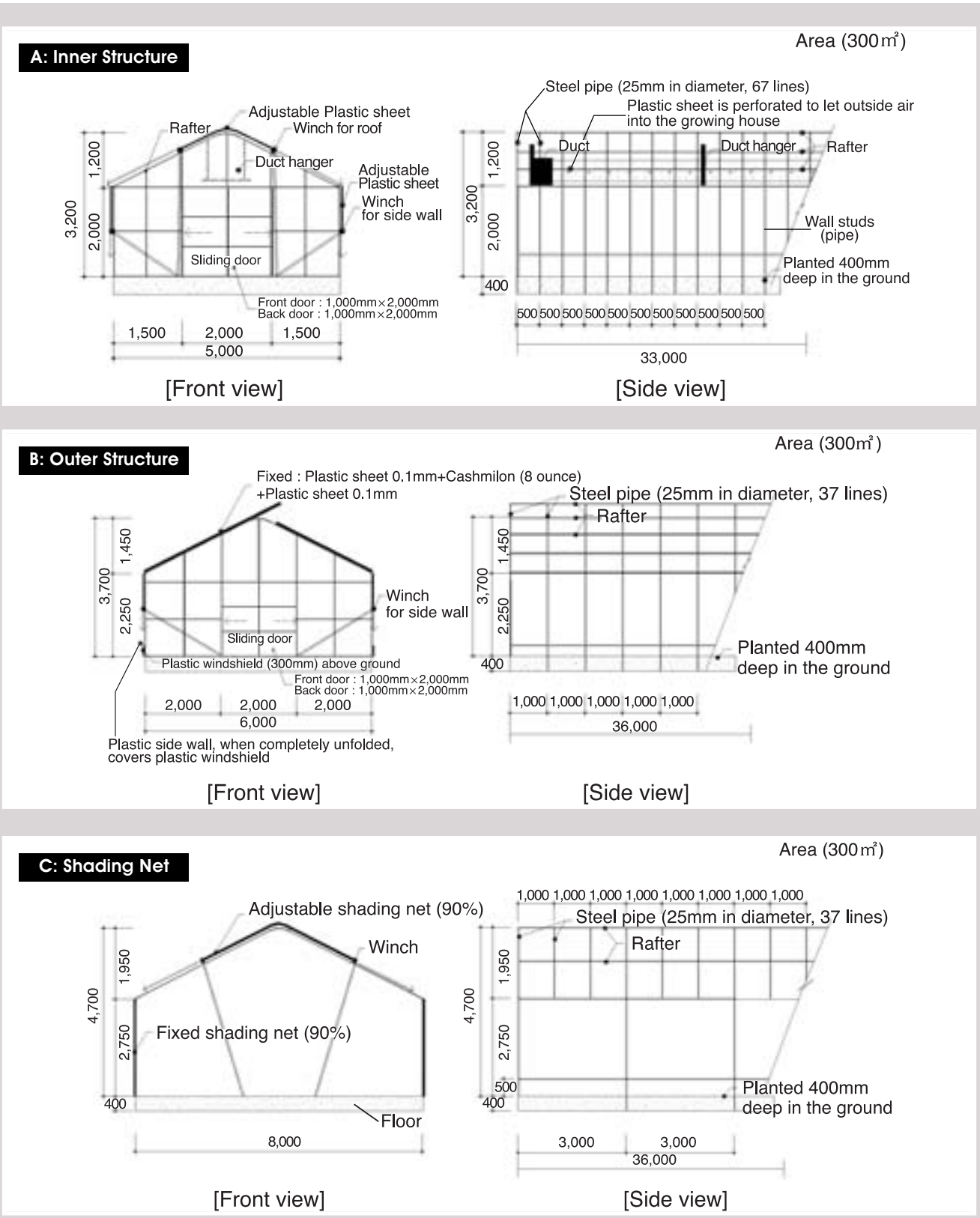

Figure 8. Plans for the three folded overlapping open roof growing house **A**: Inner structure **B**: Outer structure **C**: Shading net structure

Construction step 2: plastic cover and shading nets

Figure 9. Plastic sheet of inner structure rolled up

Inner structure: The interior structure is under the protection of outer structure, so the 0.1mm plastic film is sufficient. Two sets of winches are installed on the inner structure. One is for controlling the arch roof and the other is for raising and lowering the side walls (Fig. 8A). Figure 9 shows the plastic film of the inner structure fully rolled up on the arch roof.

Outer structure: The outer structure consists of two sheets of 0.1mm plastic film and 8 ounce cashmilon. A winch is equipped on side wall to roll up the outer layer up to where side wall meets the arch roof (Fig. 8B). The most important structure is the open roof section of the outer structure. In order to prevent damage to the plastic and shade netting from repeated rolling up and down, two protective pads are attached to each structure of the culture house as shown in Figure 10C.

Outside shading nets: Shading net blocking 90% light is used, and this is attached only to the top part of the frame in order to be able to roll up the net (Fig. 8C).

Figure 10. Roof of outer structure **A**: Framework of open roof part **B**: Overlapping open roof covered with plastic films and cashmilon, and the structure for shading net above it **C**: Sketch of open roof part

Construction step 3: equipment and the floor

Once the structure is erect and covered, the various doors, ducts, boilers and drainage systems are installed. A radiator that uses underground water with a year round constant temperature is employed for cooling and heating in summer and winter. The aisles are covered with cloths for water control and the floor is raised below the shelf frames in order to prevent water puddling and ensure adequate water drainage.

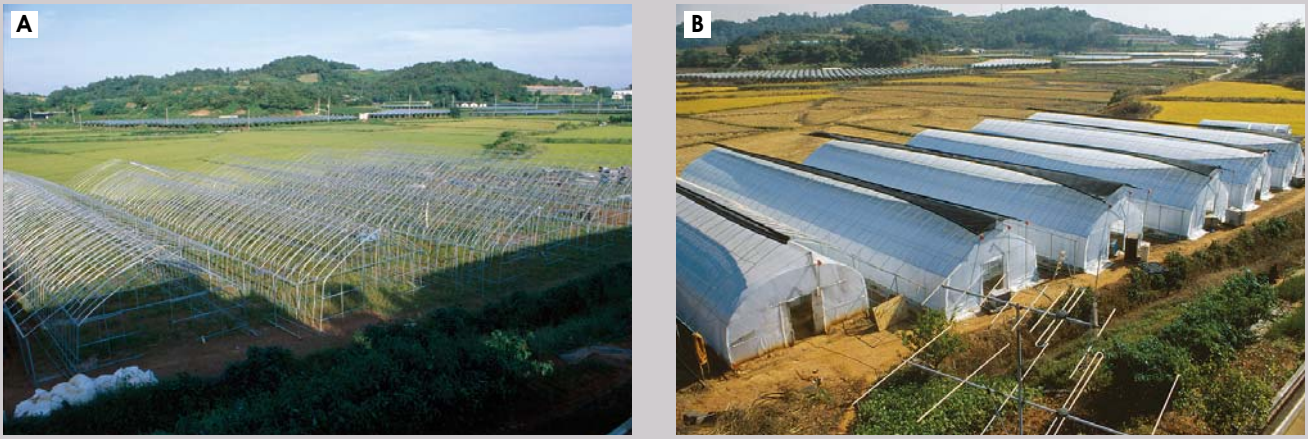

Figure 11. Growing houses with threefold structure under construction **A**: Completed framework **B**: Completed covering with plastic films and shading nets

Growing House Management

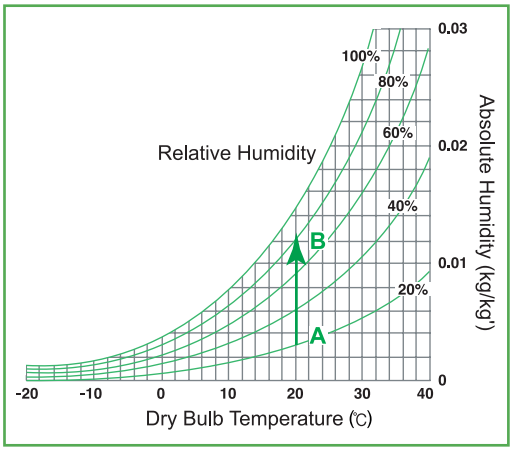

Figure 12. Psychometric chart

Environmental management of a growing house aims to provide an appropriate environment for shiitake production. The psychometric chart shown here (Fig. 12) shows relative humidity and absolute humidity relevant to the changing temperatures.

For example, if a farmer wants to adjust the current state A (20℃ temp., 20% R.H.) to B (20℃ temp., 80% R.H.) in Figure 12, they can see from the chart that absolute humidity is 0.003 now, but when 80% R.H. the absolute humidity is 0.012. So, assuming the volume of growing house is 1,000m^3, (0.012–0.003) ×1000=9, which means we have to vaporize 9kg water into humidity and introduce this into the house.

Temperature

The key point of temperature control is cooling in the summer. Unfolding the shading net will block the sunlight. The outer structure can be rolled up to the shoulder of the house, and the inner structure can be opened to the top for efficient ventilation. The roof of the outer structure can also be opened to let the rising hot air be sucked up for the release to outside. When the air temperature goes up over 30℃, the underground water with a constant temperature of 15℃ is sprayed and the inside temperature can be lowered by 3℃. In winter, the overlapping roof can be closed, the shading net folded and all the side walls closed. When necessary, a boiler can be operated to blow warm air into the house (Fig. 13A).

Figure 13. Equipments for environmental management **A**: Boiler **B**: Duct

Watering and ventilation

Watering inside the house creates enough humidity to the growing house as well as lowering the temperature. Ventilation is required after watering in order to dry the wet surfaces of the bags. In the rainy season (late June to mid July) with a 100% relative humidity, green mold is more likely to attack shiitake bags, so forced ventilation is used to blowing dry cool air inside the house.

Ventilation also provides fresh air for mycelial growth and fruiting. To produce flower shiitake, growers need to inject sufficient water into the substrate while lowering the relative humidity inside the growing house. A water injection kit is very useful for injecting water into the shiitake substrate (Figs. 14).

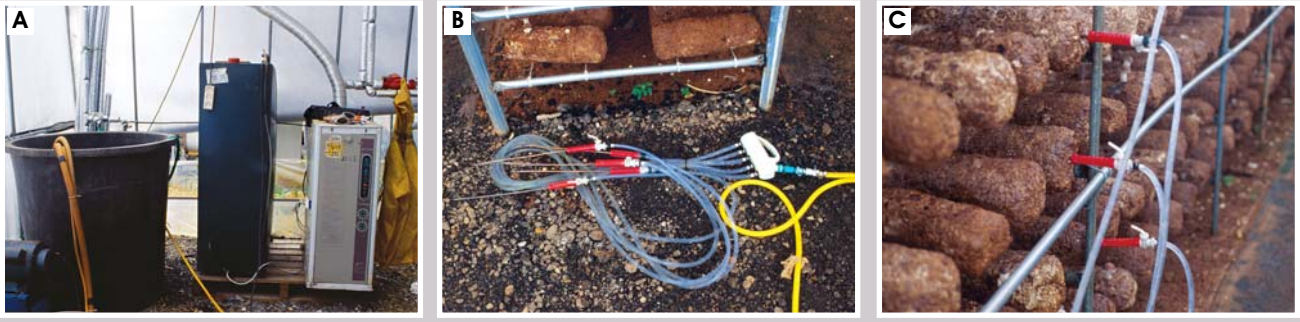

Figure 14. Equipments for watering-water injection kits **A**: Water tank **B**: Water distributor **C**: Needles

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