Part Ⅱ Mushroom for Better Life

Chapter 10

Regional Studies

MUSHROOM GROWING IN LAO PDR

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Introduction

Environment

The Lao People's Democratic Republic was proclaimed and officially declared a Marxist-Leninist government in December 1975. A new economic reforms policy designed to create a market-oriented economy was launched by the Laotian Govern-ment in 1986. Since that time the Lao PDR has opened itself widely to the world.

Lao PDR is landlocked, with an area of 236,800km², 6,000km² of which are bodies of water and 230,800km² land. The country sits at 18° N longitude, 105° E latitude, in southeastern Asia, and is surrounded by Vietnam, Thailand, Cambodia, China and Myanmar. Lao PDR stretches 1,700km from north to south and is between 100-400km wide from east to west. The climate is typical tropical monsoon weather, with a cool season having temperatures down to 16℃ that lasts from October to February. The short warm has temperatures up to 40℃ from March until April, and the rainy monsoon season runs from May through September.

Figure 1. Map of Lao PDR

In Lao PDR, rice cultivation occupies 627,000ha and produces 1.72 million tons per year. Maize cultivation occupies 28,000ha and produces 56,000 tons per year. Cassava and sweet potato cultivation occupies 15,000ha and produces 160,000 tons per year. Vegetable cultivation occupies 16,500ha and produces 156,000 tons per year. Laotian farmers also cultivate soybean, mung bean, groundnut, sugarcane, white sesame, kapok, cotton, sawdust, cattle, water buffalo, horse, chicken, and duck (DDFI, 2003).

Brief history of mushroom cultivaion

Rice is the main crop of the people who live in this monsoon climate. From June to October the main fields are under water, and only rice crops can grow under these conditions. Other crops are grown after the rice harvest. Straw mushroom is a crop which can earn growers enough money to survive with throughout the year. The large quantities of rice straw left after the harvest can be used as substrates for the cultivation of straw mushrooms. The cultivation process is very simple and productive.

The knowledge of how to grow straw mushrooms is limited to those farmers who have earlier participated in the training that was provided by the government officials through supporting international agencies such as UNDC, FAO, and JICA. In 1996, the Lao PDR government sent a group of government officials and farmers to get training in mushroom growing at Kanlasin in Thailand. After that session, the trainees came back to Lao PDR and constructed a mushroom training center with support from The Soil and Crop Extension Center, the National Agriculture and Forestry Extension Service, and the

Ministry of Agriculture and Forestry. Mr. Kenkham Bouphaniveth, one of the trainees who had been trained in Kanlasin came to work as a mushroom production engineer. The facilities for mushroom growing were set up as a trial mushroom farm and demonstration area. More than 500 extension service officials and farmers have attended training in this center as of Dec. 2004. Ajarn Bouavone Duangdeuane is another alumnus of the training in Kanlasin. He now teaches mushroom cultivation at Luang Prabang Agriculture and Forestry College and many mushroom growers in Luang Prabang are his students. Ajarn ComeSingh, another graduate of the Kanlasin mushroom training program is a mushroom specialist who has trained many students at the Faculty of Agriculture, in the National University of Lao PDR. Many graduates of this program have become the mushroom extension service officials and growers. Mr. Kammune, another Kanlasin training attendee, works at the Seed Multiplication Center, Department of Agriculture, Ministry of Agriculture and Forestry in Na Phok as a mushroom specialist. He built the pilot project for mushroom cultivation that lasted for two years and acquired enough knowledge and experience to run the demonstration farm and he is going to organize future mushroom training courses for officials and farmers.

Straw mushroom cultivation in Lao PDR is limited to the few months after the rice harvest. Some other straw mushroom growers use banana leaves obtained from the banana plantations. Despite the fact that straw mushrooms can be more profitable than any other crop, growing of straw mushroom can be complicated and hard work for the average farmer; and this crop seems to suit only the certain few who would be good at any job.

Mushroom Species

Through observations and interviews with mushroom sellers it has been determined that most of the mushrooms that are sold in the markets are species imported from Thailand. Most of the mushroom species grown in Lao PDR are brought directly from TMCC (the Thailand Mushroom Culture Collection. Tel: +662-5790147, +662-5614673, Fax: +662-9406371) or indirectly through mushroom accessories suppliers. In 1996, TMCC had in its collections 16 species and 750 strains of cultures. They now distribute 15 species and 40 different strains to growers. In the collection there are 18 strains of straw mushroom (*Volvariella volvacea*), 60 strains of white mushroom (*Agaricus bisporus*), 79 strains of brown mushroom (*Agaricus bitorquis*), 332 strains of shiitake (*Lentinus edodes*), 190 strains of oyster mushroom (*Pleurotus* spp.), 16 strains of wood ear mushroom (*Auricularia* spp.), 18 strains of linchu (*Ganoderma lucida*), 4 strains of Hed KhonKaaw, 5 strains of Hed KraDaang, 5 strains of Hed TheenRad (*Tricholoma crassum*), 8 strains of enokitake (*Flammulina velutipes*), 4 strains of yanangitake (*Agrocybe*

Figure 2. Mushroom species **A**: Hed Cone (Termitomyces sp.) **B**: Hed NangFah-Bhutan (Pleurotus pulmonarius) **C**: Hed NangLom (Pleurotus ostreatus) **D**: Hed Khamint (Cantharellus cibarius) **E**: Hed Fuang (Volvariella volvacea) **F**: Hed Boad (Lentinus sp.)

cylindracea), 1 strain of purple oyster mushroom (*Pleurotus salmonicolor*), 1 strain of monkey head mushroom (*Hericium erinaceus*), 2 strains of porcini mushroom (*Boletus* spp.), 2 strains of Hed Kraeng (*Schizophyllum commune*), 1 strain of shimejitake (*Hypsizygus marmoreus*), 1 strain of Hed Tuo (*Coprinus comatus*), 1 strain of white jelly mushroom (*Tremella fuciformis*), 1 strain of Hed HooKwang (*Lentinus strigosus*), and 1 strain of Hed TheenPlog. TMCC annually provides 6,500-8,500 bottles of mushroom cultures to 250 growers and 20 agencies. A quantity of this goes to the Lao PDR through mushroom spawn providers.

Table 1. Cultivated mushrooms in Lao PDR

Scientific name	Local name(common name)	Scientific name	Local name(common name)
Volvariella volvacea (Bull. Ex Fr.) Sing.	Hed Fuang, Hed Faang, Hed Boa (straw mushroom)	*Lentinus polychrous* Lev.	Hed Lome, Hed KraDaang, Hed Boad
Auricularia auricular(Hook.) Underw. *Auricularia polytricha* (Montagne) Saccardo	Hed HooNooh (wood ear mushroom)	*Lentinus squarrosulus* Mont.	Hed KohnKaaw
Pleurotus ostreatus (Jacquin ex Fries) Kummer	Hed NangRom (oyster mushroom)	*Lentinus sajor-caju* (Fr.) Fr.	Hed TheenPlog
Pleurotus pulmonarius (Fies) Quelet	Hed NangFaa, Hed NangFaa Bhuthan (angel mushroom, Indian oyster mushroom)	*Lentinus giganteus* Berk.	Hed Thongfone
Pleurotus abalonus Han. *Pleurotus cystidiosus* O. K. Miller	Hed PhoaHuu (abalone mushroom)	*Coprinus cinereus* (Schaeff. Ex. Fr.) S. F. Gray	Hed TuaNoa (ink cap mushroom)
Lentinus edodes(Ber.) Sing.	Hed Hom (shiitake)		

Table 2. Native (wild) species seasonally available in the local markets

Scientific name	Local name(common name)	Scientific name	Local name(common name)
Astraeus hygrometricus (pers.) Morg.	Hed Thop, Hed Phor, Hed Hiank, Hed Payom (earth star)	*Russula cyanoxantha*	Hed NaahMoi
Termitomyces fuliginosus Heim	Hed Pluag, Hed Cone (termite mushroom)	*Russula rosacea* Pers. Ese Gray	Hed Deang, Hed Hed GulahbDeang, Hed ThaKleiDeang
Amanita caesarea (Fe.) Schw.	Hed KhaiHaanLuang, Hed RangokLuang	*Dictyophora duplicata* (Basc. ex. Fr.) Fisch.	Hed Phai, Hed RaangHae (dancing mushroom)
Amanita princeps Corner & Bas	Hed KhaiHannKaaw, Hed RangokKaaw	*Phaeogyroporus prolentosus* (Berk. et. Broome) Mc Nabb	Hed Haa
Russula delica Fr.	Hed Klei, Hed Thaclei, Hed Lohm (grass-white russula)	*Cantharellus cibarius* Fr.	Hed KhamintLuang, Hed ManPhoo
Russula aeruginea Lindbl.	Hed KleiLhaangKiew, Hed thacleiLhangKiew, Hed LohmLhangkiew (grass-green russula)	*Lactarius volemus* (Fr.) Fr.	Hed Faan

Cultivation

Open field cultivation of straw mushroom

Open field growing is simple and cost effective. During December, the farmers will harvest and thrash rice in the fields. Rice straw bundles are then moved and soaked overnight in small mud-ponds (Figs. 3). The next morning, the wet straw is carried from the pond to the growing site by a small cart hooked to a motorcycle (Figs. 4).

The farmers then put 15-20cm of wet straw in a frame that measures 35-40cm at base, 25-30cm at the top, 35-40cm in height, and 100-150cm in length (Figs. 5). The farmers make a spawn mixture with one part spawn and 10-20 parts supplement (Fig. 6A). Sawdust, mung bean or soybean-husks, rice bran, kapok pits, manure, compost, organic fertilizer, cotton waste, soybean meal, and malt residue can be used as supplements. They place 5-7cm of this spawn mixture parallel to the margin of the substrate pile, making 2-4 layers, depending on the weather, and making more layers in cool months (Figs. 6B and C). The growers make 40-44 or more piles, placing each 15-20cm apart from the others (Figs. 7). The piles are then covered with

thin plastic sheet and shaded with straw pads on bamboo frames for 5-7 days (Figs. 8A and B). The growers then take off the plastic sheet, water as needed, and then put together the bamboo frame cover with a plastic sheet and straw pad. In 3-5 days the first flush of mushrooms can be harvested. The crop will continue for 3-4 more flushes. The production from one pile of substrate will be 1-3kg, depending on the quality of the spawn, the supplements, weather and maintenance.

Figure 3. Straw soaking **A**: Straw carrying **B**: Loading down straw to the pond **C**: Soaking straw for one night

Figure 4. Moving the wet straw to growing site **A**: Loading wet straw on the cart hooked to a motor-cycle **B**: Unhooking motorcycle **C**: Unloading wet straw from cart

Figure 5. Making bed **A**: Steel bar & galvanized sheet frame **B**: Laying the frame **C**: Putting in straw

Figure 6. Inoculation **A**: Spawn & supplements (dried cattle manure and rice bran) mixing **B**: Putting the first layer of mushroom spawn into two rows **C**: Putting in the last straw layer

Figure 7. Completing the bed **A**: Pressing to compact **B**: Taking out the frame **C**: One plot (40-44 blocks) takes a half day to prepare.

Figure 8. Plot and pinning **A**: Plastic-sheet covering **B**: Shading by straw with bamboo-frame **C**: Fruitbody initiation

Table 3. Cost of each item

Item	LAK[1] / kg	LAK/bed	LAK/44 beds (USD)
Straw	750 / bag	750 × 4=3,000	132,000 (16.8)
Spawn	5,500	5,500 × 0.75=4,125	181,500 (23.1)
Rice-bran	1,500	1,500 × 7.5=11,250	495,000 (63.1)
Ox-dung	250	250 × 7.5=1,875	82,500 (10.5)
Kapok-pit	1,125	1,125 × 7.5=8,437.5	371,250 (47.3)
Cotton-waste	2,250	2,250 × 7.5=16,875	742,500 (94.7)
Cassava-root bark	250	250 × 7.5=1,875	82,500 (10.5)
Sawdust	100	100 × 7.5=750	33,000 (4.2)
Plastic sheet	40,000	40,000 / 44=909.1	40,000 (5.1)
Bamboo		1,000	44,000 (5.6)

Bag cultivation of other mushrooms

Northern and north-eastern Thailand and the Lao PDR have native mushrooms that are mainly wood rotting mushrooms (Table 4), and can be found on many kinds of trees such as Mai-Teng (Rung, Hiang, Thakian, *Hopea odorata* Roxb.) and Krabahg.

Table 4. Native wood rotting mushrooms

Scientific name	Local name	Scientific name	Local name
Pleurotus ostreatus	Hed NangRome	*Pleurotus pulmonarius*	Hed NangFaa
Auricularia auricula	Hed HooNooh	*Ganoderma lucidum*	Hed LihnJuu
Phellinus linteus	Hed TheenChaank	*Macrocybe crassa*	Hed Jaan
Lentinus polychrous Lev.	Hed Lome or Hed Boad	*Lentinus squarrosulus* Mont.	Hed KhonKaaw
Lentinus sajor-caju (Fr.) Fr.	Hed TheenPlog	*Lentinus giganteus* Berk.	Hed ThonkFone

[1] LAK (Lao Kip, USD1 ˙, LAK7,843 in February, 2005)

1) Substrate preparation
   a) Sawdust in Luang Prabang is available in large quantities from many sawmills, and it is free for anyone who needs it. In Vientiane, sawdust is available from a truck loader who offers sawdust at LAK200,000 per truck, which is an amount that can fill 2,000-3,000 of the 7 ×12 inch plastic bags. The cost for this sawdust will be LAK75-100 per bag.
   b) There is straw left in the rice field after harvesting.
   c) Rice bran and broken rice are available from small rice mills or animal feed shops at about LAK100 per kg and LAK200 per kg respectively.
   d) Sugar is available from any grocery at LAK4,000-5,000 per kg.
   e) Lime is available from hardware shops at LAK6,000 per 8kg bag.
   f) Magnesium sulfate and gypsum are available from mushroom suppliers at LAK6,000 per kg.
   g) Other accessories such as plastic necks (THB[2] 250 per bag; each bag has 700-900 pieces) are available from the supplier.
2) Fill substrate into a 7 ×13 inch plastic bag; Compact to 2/3; Put on neck; Put on cotton plug; Wrap paper on cotton plug
   Formula 1: 100kg sawdust (para rubber, tamarind), 3-5kg rice bran, 0.5-1kg lime or calcium carbonate or gypsum, 2-3kg sugar, 50-55% water content
   Formula 2: 100kg mixed sawdust, 1kg ammonium sulfate, 1kg lime; mix with water and leave to ferment for 2-3 months, then mix with the following; 3kg rice bran, 2kg sugar, make 50-55% water content (Arahmpong-pan and Pimkarn, 2001)
   Formula 3: 100kg sawdust, 3-5kg rice bran, 3kg sugar, 0.2kg magnesium sulfate, 1kg calcium carbonate, and 60-65% water content
   Formula 4: 100kg sawdust, 5kg rice bran, and 70% water content (Petcharat, V., 1995)
   Formula 5: 100kg sawdust, 5kg rice bran, 5kg broken rice, 2kg sugar, 1kg lime, 0.5kg magnesium sulfate and 55-65% water content (Chanthacoad *et al*., 2003)

Figure 9. Weighing a substrate bag

Table 5. Various formulae from survey

Survey No.	Sawdust (kg)	Rice straw (kg)	Rice bran (kg)	Broken rice (kg)	Sugar (kg)	Lime (kg)	Gyp. (kg)	Mag. (kg)	Vit. B_1 (g)	Water Cont. (%)
1	100	-	5	5	2	1		0.5	-	55-65
2	170	70	15	5-7	-	2	-	0.4-0.6	-	50-60
3	100	-	5	3	2	1	-	0.2	-	55-65
4	100	-	7	5	2	1	-	0.5	-	55-65
5	100	-	5	3	2	0.5	0.5	0.2	1	55-65
6	100	-	5	5	2	1	-	0.2	-	55-65
7	100	-	5	5	2	1	-	5	-	55-65
8	100	-	5	5	2	0.5	0.5	0.2	-	55-65
9	100	-	5	3	2	0.5	0.5	0.2	-	55-65
10	100	-	5	5	2	1	-	0.5	-	55-65
11	100	-	5	5	2	1	-	0.5	-	55-65
12	100	-	3-5	-	2-3	1	-	0.2	1	60-70
13	100	-	6	3	-	-	0.2	0.2	1	60-70
14	100		7	3	2	0.5	0.5	0.2	1	60-70
15	100	-	3-5	-	2-3	1	-	0.2	1	60-70

3) Load 100 substrate bags into a 200 ℓ oil drum; Cover the 100 substrate bags above the oil-drum with a garbage plastic bag; Boil until the steam builds up; Use a needle to punch small holes in the garbage bag to let excess steam escape from the drum; wait for 3-4 hours. Stop boiling and allow the drum to cool down to room temperature (Figs. 10).
4) Inside the inoculating room; Inoculating with grain spawn (1 bottle for 20-30 bags) (Fig. 11).

[2] THB (Thai Baht, USD1 ·, THB38.30 in February, 2005)

5) Carry the bags into the incubation room; Incubate them at 28-32℃ for 30-35 days (Fig. 12). The white mycelium will grow and cover all parts of the substrate surface and start to initiate fruitbodies. For Hed Boad the mycelium will turn to orange or iron-rust color and then to dark-brown till black when it is ready to initiate fruiting. This fruiting will take place 80-90 days after inoculation.

Figure 10. Drums for pasteurization **A**: Drums on fireplace **B**: Rack inside the drum

Figure 11. Spawning **A**: Spawn bottles **B**: Spawning

Figure 12. Incubation

Figure 13. Hed Boad fruitbody

6) Bring the incubated bags into the growing house; Take out the cotton plugs from substrate-bags to make room for the fruitbodies to come out. Wait a few more days before starting the mushroom harvesting. It takes 3-5 days after the first detected mushroom primordia. In case of Hed Jant and Hed Thongfone, cut off the plastic bags then put together 5-10 pieces in one big plastic bag and put 3-5cm casing soil on the upper surface. This final packaging will cause the mycelia to produce a better quality of mushrooms
7) The harvesting can be continued for 3-5 days and the farmer can start the new fruiting cycle again in 2-3 weeks. All together the harvesting can continue for 6-8 flushes over the course of 4-6 months. Each ten bags can produce 1.5-3.0kg.

Table 6. Material costs

Item	Price (LAK/kg)	Quantity (g/100kg)	Cost (LAK/1kg bag)
Sawdust	75-100	100,000	75-100
Rice bran	750-1,250	5,000	37.5-62.5
Broken rice	1,500-2,000	5,000	75-100
Sugar	3,750-5,000	2,000	75-100
Lime	750	1,000	75
Gypsum	2,500-6,000	500-1,000	
Magnesium sulfate	3,200-6,000	200	6.4-12
Pumice	3,125		
Calcium carbonate	6,000		
Organic fertilizer	2,500		
Plastic-neck	70-90/bag	100	70-90
Plastic-bag	60/bag	100	60
Bagging	60/bag	100	60
Spawn	1,200-2,000/bottle	4-5 bottles	48-100
Ready to open	1,200		
Wage	20,000/day		800-1,200*
Growing house	1,500,000/house**		8.3***

* Wages for 1 worker, 4-6 months employment from inoculation to crop ending
** 1 standard growing-house (4 ×8 ×3.5m) contains 3,000 bags/6 months/6 crops
*** 3 years usage

Spawn

Spawn is considered the seeds or seedlings of mushroom plants. Spawn is made by culturing mushroom spores or tissues on agar media for a few days until the white-threaded mycelium emerges from the spores or tissue. This mycelium will be then multiplied on cooked cereal grains for 10-15 days. The mycelium growing on the cereal grains can then be used as mushroom spawn.

Good quality spawn can lead to success in mushroom cultivation. The criteria for quality mushroom spawn include:

1) The starting culture should be a good strain, obtained from a government agency or university that has screened for the best from among many different sources and/or developed the strain via hybridization and/or mutagenesis. Because there is not a government agency that works on this matter in the Lao PDR, most of the starting cultures are brought from Thailand. The cultures cost THB70/bottle in Thailand and are then sold in the Lao PDR for THB100/bottle. If this starting culture is subcultured more than two or three times, the spawn degenerates and this results in lower yield and abnormal fruitbodies.
2) The starting culture and resulting spawn should be free from pests and diseases. A good spawn provider will inspect their products before selling them to their clients. These inspections for mites and molds can be done with a magnifying glass.

Figure 14. Sorghum grain spawn from Thailand

Figure 15. Imported sorghum grain spawn

The procedure used in spawn production is as follows:

1) Imported starting culture: The starting culture from Thailand will be on PDA (Potato Dextrose Agar) slant in small whisky bottle, which can be transferred to 50-60 subcultures on PDA in small whisky bottles (Fig. 16). Each can be used to inoculate rice grains in medium size whiskey bottles and will be sold as spawn to the growers at LAK1,200-1,500 (USD0.15-0.19) per bottle. One bottle of spawn can be used to inoculate 20-30 growing bags.

2) PDA preparation: Peel out the skin of 200-300g potato and cut it into small pieces; boil them in 1,000㎖ water for 15 minutes; filter out the pieces and take the filtrate liquid; put in 15-20g agar and stir till the agar dissolves in the liquid; put in 20-40g dextrose (D-glucose, sugar) and stir to dissolve. Use funnel to fill 20-30㎖ PDA solution in flat Maekhong whiskey bottle; put in cotton plug; wrap up the plug with paper sheet by rubber band; sterilize the PDA bottles in autoclave at 15 psi, 121℃ for 20-30 minutes; take out from autoclave to make slant and cool down.

3) Tissue culture: Mushroom tissue culture will be made by sterilizing cutter or isolating needle in sterilizing solution (10% clorox or 70% alcohol or 3% hydrogen peroxide) for some minutes, cut a small piece of the clean part of mushroom fruitbody (unexposed to the air part), place on slant agar media inside PDA bottle (heat the bottle mouth part by alcohol flame everytime before and after opening the bottle), the operation is made in airtight cabinet (Fig. 17) (this can be made from a corrugated paper box or polystyrene foam sheet or wood), leave these bottles until the mycelium from mushroom tissue grows covering the surface of agar media.

Figure 16. Starting agar culture

Figure 17. Transferring hood from polystyrene foam

Figure 18. Home made autoclave

Figure 19. One spawn provider shows starting agar culture and behinds are the oil-drums used for substrate pasteurization.

Figure 20. Kapok pit grass

Figure 21. 200g kapok pit is used as substrate

Figure 22. 3 days after inoculation

Figure 23. 10 days after inoculation

4) Rice-grain substrate: Boil the rice grain till the core of the grains are exposed, drain out the water, dry for 2-3 hours in the sun, pour the grains into MaeKhong whiskey bottles, put in cotton plugs, wrap the plugs with a paper sheet, sterilize the bottles at 15 psi, 121 ℃ for 20-30 minutes, take out and cool down to room temperature. Use isolating needle to cut small pieces of agar (the parts covered with mushroom mycelium) from the starting culture, transfer to the grain bottles (flame heat the mouth of the bottles before and after plugging cotton and operate inside airtight hood), leave until the mushroom mycelium covers the grain, at which point it is ready to use as mushroom spawn.

5) For straw mushrooms, kapok pits (Fig. 20) or cotton residue can be used as the substrate. Soak the kapok pits or cotton waste in water for 2-3 hours, drain out the water, pack the mix into plastic bags, sterilize and inoculate in the same way as in grain spawn culture.
Some spawn providers make spawn by soaking the kapok pits in water for 2-3 hours, draining off the excess water, mixing with sorghum grain spawn or cotton waste spawn from Thailand (1 spawn : 10-20 kapok pit), making a pile 30-45cm height, covering the pile with a plastic sheet, leaving the mix for 5-7 days, then putting it in a plastic bag, and selling it as straw mushroom spawn (Fig. 21).

Mushroom Growing Houses

Figure 24. Imperata grass roof with two stacks of substrate bags as the walls

Figure 25. A house covered with a plastic sheet made from fertilizer bags in order to raise the temperature and humidity for Hed Boad

Figure 26. Corrugated paper from old boxes is used for the walls and ceiling. These carton box materials are already over 3 years

Figure 27. A standard (4 × 6m) government instructed growing house

Figure 28. A 4 × 6m standard growing house at the Mushroom Experiment and Extension Service Center

Figure 29. Airtight growing house. It can be fumigated to control pests and diseases.

Figure 30. This growing house has its whole sides covered with Imperata grass to prevent flies.

Figure 31. Roof structure

Figure 32. Rack frame structure

Pests and Diseases

Sciarid fly (*Lycoriella* spp.), Phorid fly (*Megaselia* spp.), springtails (*Leidocyrtus* spp. and *Achorutes* spp.), mites (*Luciaphorus* sp.), green mold (*Gliocladium* sp., *Trichoderma* spp., *Penicilium* sp. and *Paecelomyces* sp.), black mold (*Aspergillus* spp. and *Botryodiplodia* sp.), orange mold (*Neurospora* sp.), slime mold, brown rot (*Pseudomonas tolaasii*), and brown spot and yellow rot (*Pseudomonas fluorescens*) are common and often found in plastic bag mushroom cultivation operations.

Figure 33. Minute flies on oyster mushroom

Figure 34. Mite damaged bag

The principal reasons for pest problems are:

1) The growing house is near to the sources of pests and diseases.
2) The old substrate bags and the new ones are in the same room.
3) Diseases and pests in any infected bags are not eliminated from the growing room.
4) The used substrate bags and the infected ones are not treated properly. They are merely thrown out and left at the front door or a few yards from the growing house (Fig. 35).
5) The growing rooms and incubation rooms share the same space. In this way mites from the old bags can find new food sources (Fig. 36).
6) The growing rooms and incubation rooms are not airtight. Fumigation could not be performed. The houses are too easily accessed by flies entering the growing rooms with mites carried on their bodies.

Figure 35. Damaged bags sit alongside the good ones

Figure 36. New bags sit next to the old ones

Keeping out flies is very helpful. In one case in Luang Prabang, a farmer using corrugated paper board from old boxes as a ceiling and wall material for his growing house. Screen nets at the doors and opening parts keep flies out of the house, and this precaution results in his mushroom houses being clean and free from mites and green mold.

An airtight room could be created easily by using plastic film, or old sheets of newspaper coated with flint coat, or the

paper from old portland cement bags. Fumigation could then be performed simply way by using sulfur powder in a hot pan. In many cases, mites were detected in mushroom spawn. In this case, a 100% infection rate with green mold will follow. A magnifying glass is very helpful to detect mites. Phosphine fumigation should be performed by mushroom spawn providers before providing spawn to their clients. Many cases of mites result from having visitors who have recently visited another mushroom farm. Any workers who have performed mushroom harvesting in the morning should not come to work in the inoculating and incubating area before washing themselves and changing into fresh clothing.

Some mushroom spawn providers have started introducing *Bacillus subtilis* from Thailand for green mold control, and their results are promising. The *Bacillus subtilis* producer advises that, the application for *Bacillus subtilis* should proceed as follows:

Use coconut fruit, open the top and put 1g of *Bacillus subtilis* powder into the coconut. Close the opened part and leave the coconut over night. The next day the mixture in the coconut is ready to be mixed with 20*l* of water, and this mixture can be used for spraying green mold infected areas. This mixture will reduce current infections and prevent future infections of green mold. A similar procedure is also used to prepare strains of *Bacillus thuringiensis* that could control minute fly larvae in the growing substrates. The results of this are still limited. In the future a preparation useful against Steinema nematode will be experimented with by the Thai spawn supplier.

Many kinds of herbs are used in controlling pests and diseases. Garlic, cinnamon bark, eucalyptus leaf, neem seed, citrus peel and lemon grass are extracted by alcohol (whiskey) or vinegar and applied along with chitosan. Yellow glue strips are also used to trap and monitor flies and mites.

Marketing

Table 7. Cost of production (LAK/kg)

Mushroom	Substrate	Plastic bag, neck	Spawn	Labor	Depreciation
Oyster	300-500	100	10	100	100
Angel	300-500	100	10	100	100
Wood ear	300-500	100	10	100	100
Lentinus	300-500	100	10	100	100
Straw	100-200	50	20	50	30

Table 8. Buying and selling price (LAK/kg)

		Oyster M.	Angel M.	Wood ear M.	*Lentinus* M.	Straw M.
Luang	Wholesale price	2,000	7,000-9,000	6,000-9,000	12,000-15,000	-
Prabang*	Retail price	2,200-2,500	12,000-15,000	12,000-15,000	15,000-20,000	-
Vientiane**	Wholesale price	7,000	6,000-9,000	7,500	12,000	12,000
	Retail price	9,000	9,000-15,000	10,000	15,000	15,000

* Luang Prabang: Posy Market, Mitthaparb Market
** Vientiane: Luang Market, Khuawdin Market

Figure 37. Posy market, Luang Prabang **A**: Vegetable retailer displays wood ear mushrooms among others **B**: An oyster mushroom grower sells her mushrooms on the ground

Figure 38. At the Mitthapab market in Luang Prabang, wood ear mushrooms are sitting among chili, galangka, curmint, and peppermint.

Figure 39. Thongkankhum market, Vientiane **A**: 10kg at LAK9,000 per kg, but 1 kg is LAK12,000 **B**: High quality oyster mushroom (Pleurotus ostreatus) at LAK9,000 per kg **C**: At another corner sellers can get LAK15,000 per kg

Figure 40. Khuawdin market, Vientiane **A**: Local high quality straw mushroom at LAK15,000 per kg **B**: These two growers sell their angel mushrooms **C**: High quality oyster mushrooms

Figure 41. Kad Luang **A**: One bag is filled with 0.5kg oyster mushroom, wholesale is LAK8,000 and retail is LAK9,000 **B**: Hed TuaNoa are the second most popular mushrooms after straw mushrooms. **C**: Hed KohnKaaw the favorite mushrooms from the jungle are now imported from Thailand

Potential for Mushroom Development

Straw mushrooms is considered an important ingredient in Tomsaep (spicy soup), which is an important item in the Laotian people's diet. The demand for these mushrooms is high at all times of year. Straw mushrooms can be found around rice straw piles and banana plantation piles in limited quantities during the rainy season. During this period most mushrooms in the market are cultivated mushrooms. Some few of these cultivated straw mushrooms are cultivated openly in the rice fields, but many tons of straw mushrooms are imported from Thailand every day.

One particular straw mushroom spawn provider supplies know-how and growing materials to the Lao PDR's straw mushroom growers. There is also a booklet on "The Method of Straw Mushroom and Oyster Mushroom Cultivation" in the Lao PDR that was published by the Lao PDR government. The publishing department of the Government also provides growers with educational materials. There are facilities and persons that have considerable knowledge and experience in mushroom cultivation at the Faculty of Agriculture of the National University of Lao PDR Luang Prabang Agricultural College. The seed multiplication Center, Nah Phok, the Department of Agriculture (DOA), the Ministry of Agriculture and Forestry (MOAF), the Soil and Crop Extension Center, the National Agriculture and Forestry Extension Service, the Ministry of Agriculture and Forestry could all develop very helpful programs to help the people learn and practice mushroom cultivation.

There are many waste-products from agriculture and industry which can be used as straw mushroom substrates. These include rice straw and stumps, banana stems and leaves, soybean and mungbean stems, leaves and seed husks, kapok husks and pits, cassava leaves, stems, roots, and bark, sweet potato stems and leaves, water hyacinth, corn stems and leaves, sugarcane bagasse, malt residue from beer factories, sawdust, coffee seed husks, and corrugated paper boxes. The Lao PDR raises 588,000 head of cattle, 73,000 goats, 1.5 million pigs, 42,000 horses, 1 million buffaloes, and 8 million chickens (Figures from Library of Congress Country Studies, 1994). The large quantity of manure produced by these animals would be good mushroom substrates or supplements.

The Lao PDR annually grows 521,788ha of rice, which produces 1,409,296 tons of grain (FAO/WFP-Special Report, 1995) and about 10 million tons of straw. If 10 kg straw can produce 1kg of mushrooms, then 1 million tons of mushrooms could theoretically be produced each year from the nation's excess rice straw. One hectare of rice cultivation can provide 6 tons of rice straw and stumps at one crop cycle, and these can be used to produce 600kg of straw mushrooms that are worth LAK4,800,000-6,000,000 (USD612-765). A similar amount of labor would earn only LAK1,000,000-1,500,000 (USD127.5-191.25) during 16-20 weeks of rice cultivation.

The spent sawdust substrate from other mushroom cultivation can be used as substrate for growing straw mushroom. This spent straw is even better than new straw, but this spent substrate is usually burned now. The spent straw substrate from straw mushroom cultivation is in turn very good for oyster mushroom cultivation, but no farmers in the Lao PDR currently use spent straw substrate from straw mushroom for this purpose.

Climate conditions in the Luang Prabang area are suited for cool climate mushrooms and there is a huge quantity of sawdust available in this area. This situation could be ideal for the cultivation of white-mushrooms (Hed Champignon, French mushrooms, *Agaricus bisporus*), shiitake (Hed Hom, *Lentinus edodes*), enokitake (silver and golden needle mushrooms, *Flammulina cylindrica*), eryngii (giant oyster mushrooms, *Pleurotus eryngii*), monkey's head mushrooms (Hed HuaLing, *Hericium* spp.), and yanagitake (Hed Conyeepuun, *Agrocybe cylindrica*). The southern part of the country grows coffee for exporting and the large quantity of coffee residue could be very good substrate for oyster mushroom cultivation. Wood and bamboo can be obtained at very low prices. *Imperata* and *dipterocarpus* leaves can be used to build semi-permanent mushroom growing houses very inexpensively. Good design of growing house could prevent pests and diseases. Excess electricity from the government's hydroelectric dam could provide clean and cheap electric power for ventilation and microclimate control for mushroom growing houses.

The Lao PDR consumes 15,000 tons mushrooms per year, a rate of 2.5kg per year per capita. This total is partly from wild mushrooms but mainly from mushrooms that are imported fresh from Thailand and dried from China. Only 2% of the available rice straw is used in mushroom production and 80% of the Lao PDR consumption of mushrooms is imported from Thailand, Vietnam and China.

The more than 650,000 tourists recorded since 2001 (Department of Domestic and Foreign Investment (DDFI)) will increase to more than 1 million. These visitors could be additional potential mushroom consuming customers for the big restaurants and hotels. Observations made in Luang Prabang showed that a pork roasting-pan restaurant called "JengishKhan roasting-pan" is very popular among the foreign visitors, and this single restaurant uses more than 50 kg of

mushrooms daily. There is potential for using mushrooms in the fast-food shops and European restaurant industries that are growing in the Lao PDR.

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