

Part I Shiitake

Chapter 4

Shiitake Bag Cultivation

SHIITAKE BAG CULTIVATION IN THAILAND

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Thailand has been involved in commercial mushroom production since the 1930's (Singh, 1998). Support has come from both government and private agencies for programs that encourage development in rural areas. The increasing demand for mushrooms in the canning and processing industry has also caused an increase in mushroom cultivation. The annual Thai mushroom production is valued at more than THB¹10,000 million (USD260 million) (Phanuthat, 2001). In Thailand, mushrooms are primarily sold in supermarkets and restaurants in the capital and other tourist areas. As the tourism and hotel business expands in Thailand, the mushroom consumption per capita also increases. Shiitake is one of the most popular, flavorful, and expensive mushrooms in the Thai markets. Shiitake cultivation in Thailand started in Chiangmai in the northern part of Thailand using wood logs. Log cultivation was one of the contributors to undesirable of forest exploitation, so the Thai government encouraged shiitake farmers to change to bag cultivation using sawdust. Shiitake is one of the most profitable mushroom crops in Thailand due to its relatively high price. Thai people usually consume fresh shiitake rather than dried. Shiitake that are not sold fresh are sent to food processing factories to be made into sauces, crackers, and other preserved products.



Figure 1. Substrate bags incubated in evaporative cooling room

Shiitake grows well in the lower temperatures of the northern Thailand region where the winter temperature is 18-25 °C. This is a good climate for the mycelial growth of shiitake and the coolness decreases the pest fungi contamination rates. Shiitake can be cultivated all year round, but the yield is distinctly higher in the cool seasons and cool areas. Therefore, most shiitake growers prepare substrate bags in June and incubate the bags for 4 months and get fruiting bodies in cool winter, November to February. While they don't grow shiitake in hot summer, March to May. On the other hand, while large scale farms equipped with cooling system (fan and pad cooling system²) prepare shiitake bags in summer in order to get fruiting bodies in rainy season with relatively cool temperature (Fig. 1). Shiitake prices drop as low as THB100-160 (USD2.61-4.16) per kg at retail during the rainy season (June-October) because of the low demand caused by the combination of abundant wild mushrooms and low tourist activity in this season. The retail price during dry season (November-May) varies from THB120-240 (USD3.12-6.24) per kg according to the markets where shiitake is sold: village market, town market, supermarket and so on.

Shiitake Grain Spawn

¹ THB (Thai Baht, USD1 = THB38.46 in March, 2005)

² For detailed information on fan and pad cooling system, see SHIITAKE GROWING HOUSES IN THAILAND AND THEIR MANAGEMENT in Chapter 6.

Most shiitake farms in Thailand utilize grain spawn³ because grain spawn colonizes substrates relatively rapidly and it is easy to use when inoculating the bags. Some farms that are troubled with rats that enjoy eating grain will utilize sawdust spawn instead in order to avoid rat damage. Many farms purchase spawn from supplier, but some large farms produce spawn for their own use. The production process of grain spawn is as following. Sorghum grains are filled into the medium-size Maekhong whiskey bottle and the bottle is plugged with cotton and covered with paper pieces (Fig. 2A). The grains are sterilized in low cost autoclave made from iron and then cooled and inoculated with inoculum (Fig. 2B). The bottles are incubated for spawn run in clean place (Fig. 2C). The recommended procedure is to shake the grain spawn bottle during spawn run and before inoculation (Fig. 2D). The recommended procedure is to shake the grain spawn bottle during spawn run and before inoculation (Fig. 2D).

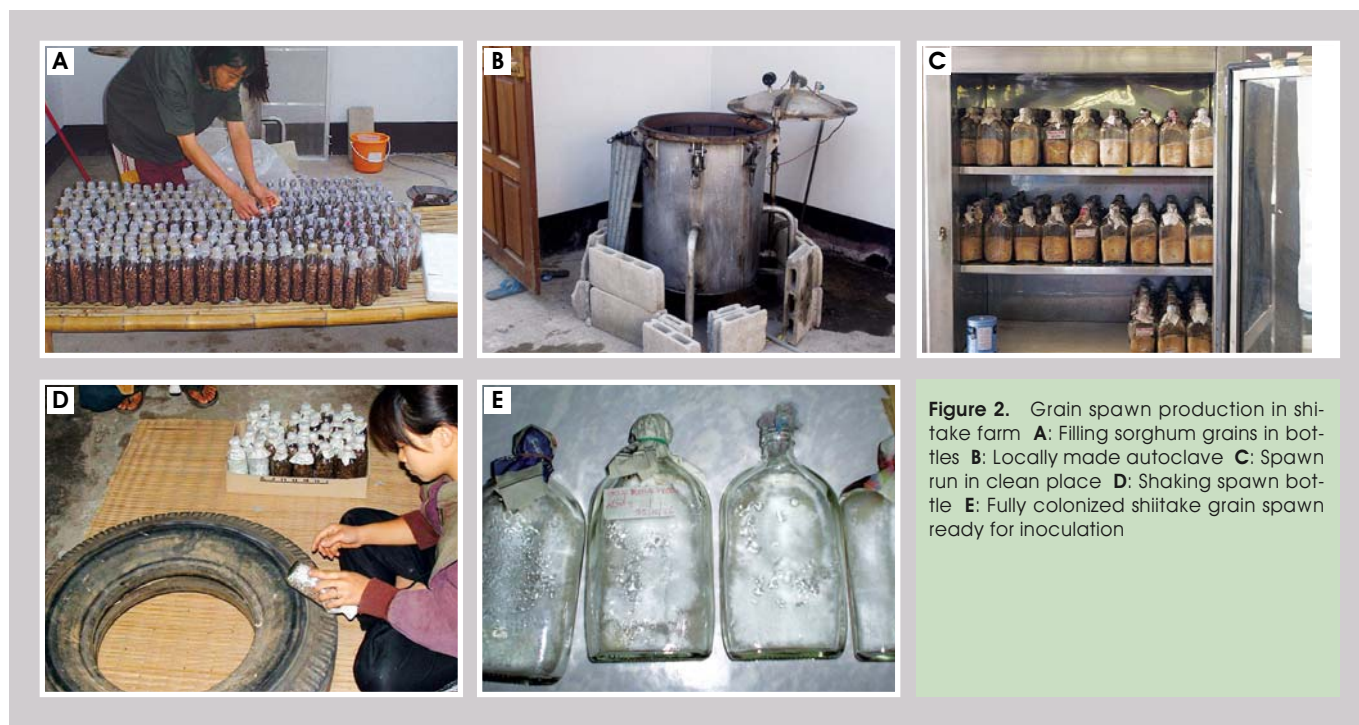


Figure 2. Grain spawn production in shiitake farm **A:** Filling sorghum grains in bottles **B:** Locally made autoclave **C:** Spawn run in clean place **D:** Shaking spawn bottle **E:** Fully colonized shiitake grain spawn ready for inoculation

Shiitake Cultivation Steps

Substrate: para rubber tree sawdust

Shiitake grows well from *Castanopsis* or *Quercus* logs. These trees play an important role in forest and soil water reservation, so cutting down these trees is prohibited in Thailand. Therefore, para rubber tree (*Hevea brasiliensis*) sawdust is used as an alternative substrate for shiitake cultivation in Thailand, and the results are satisfactory. The rubber tree sawdust is a waste product from the local furniture industry. Every year many rubber-exhausted trees are cut down to make way for new planting in the southern part of Thailand and these logs are then used as raw materials for the furniture industry. A large quantity of sawdust waste is collected in ten-wheel trucks and then transported to northern Thailand where it is used for shiitake cultivation. The price of rubber tree sawdust is about THB16,000 (USD416) per truckload of 13 tons. One truck of sawdust is sufficient to produce between 13,000 and 15,000 substrate bags (0.7-1.0kg/bag).

Substrate preparation

Rubber tree sawdust is usually left outdoor for 1-2 months for fermentation before being used, in order to get rid of volatile toxic gases. Gases emitted during spawn run could harm or kill the shiitake mycelia. After the outdoor fermentation, the dried sawdust is pre-wetted with clean water and is left on a concrete floor overnight and some supplements are added. The usual composition of the substrate material in Thailand is shown in Table 1.

Table 1. Formulation of shiitake substrate

Materials	Quantity
Sawdust	100kg
Rice bran (fine)	5kg
Sugar	2.3kg
Magnesium sulfate	0.2-0.5kg
Water	65 l

³ For detailed process of grain spawn making, see SHIITAKE SPAWN PREPARATION CHIEFLY WITH SAWDUST in Chapter 2.

Though the process of substrate preparation varies depending on farms, a shiitake farm in Chiangmai prepares substrate using the methods described here. This farm adds several supplements such as lime, calcium nitrate, and vitamin B₁ to their regular formulation. The sawdust is first screened to get rid of big particles or chips which could potentially perforate plastic bags (Figs. 3). This process is important because perforation of the bags could easily allow contamination during spawn run.



Figure 3. Sawdust screening **A:** Screening sawdust **B:** Screening machine and sorted big particles

100kg of sawdust is spread on the floor and rice bran is added at 3-5% of the weight of sawdust (Fig. 4A). One kg of lime and 2-3kg sugar are also scattered on the sawdust (Fig. 4B). One kg calcium nitrate, 0.2 kg magnesium sulfate, and 0.05kg vitamin B₁ are dissolved, and the solution is sprinkled on the sawdust (Fig. 4C). The supplements are all thoroughly mixed with the sawdust (Fig. 4D). More water is added to raise the moisture content to 60-65% and the sawdust is mixed again (Figs. 4E and F).



Figure 4. Substrate preparation **A:** Adding rice bran to sawdust **B:** Scattering lime and sugar **C:** Dissolving calcium nitrate, magnesium sulfate, and vitamin B₁ **D:** Mixing materials thoroughly **E:** Adding water **F:** Mixing materials

Bagging and sterilization

700-1,000g of the mixed substrate is put into each clear, heat-resistant plastic bag (7 inch × 11 inch). Some shiitake farms fill substrate bags manually, putting mixed substrate material into a bag and then compacting the substrate by hitting it with a rod or bottle (Fig. 5A). Compacting is not a difficult job, so it can be performed by several workers. Some larger scale

farms use a compacting machine that presses the substrate into the bags (Fig. 5B). The machine saves a great deal of time, and is highly recommended for large farms. A plastic ring is inserted as a bottle neck and the mouth is sealed with cotton plug and then wrapped with a square piece of newspaper.



Figure 5. Bag filling and compacting **A:** Manual filling and compacting with rod **B:** Compacting bags with machine

Filled bags are sterilized in an oil drum with steam. Water is poured into the bottom of the drum and metal grates are placed inside the drum to hold up the bags in each layer (Figs. 6A and B). Usually 100 bags are sterilized in a 200 l oil drum at 90-100 °C for 3-4 hours (Fig. 6C). Many farms consume hardwood sawdust or logs as fuel. The structures of the fireplace for the oil drum are different based on which fuel is used. The fireplace for sawdust has quite a distinctive structure. Sawdust is poured into the fireplace and the fire burns under the drum. As the sawdust at the bottom burns up, the upper sawdust slides into the fire place. Figure 6D shows fire place full of sawdust and as the sawdust burns up, it shrinks as shown in Figure 6E. The fireplace structure for logs is designed to fit that specific fuel (Fig. 6F).



Figure 6. Sterilization of bags in oil drum **A:** Inside oil drum (there is water under the metal grate) **B:** Metal grate holding bags up in each layer of drum **C:** Oil drum filled with bags **D:** Substrate sterilization in a big drum (fuel-sawdust) **E:** The structure of fire hole for small drum **F:** Fireplace for logs

Inoculation

When sterilization is completed, the bags are moved to a cooling room and cooled to the ambient temperature at 30℃ (Fig. 7A). Grain spawn is inoculated into the cooled bags. Several grains are poured into the bag and it is wrapped again with a cotton plug and newspaper. It is recommended that the spawning environment be kept very clean, so many farms have separated the inoculation process and it is performed in after disinfecting the inoculation room with 70% alcohol before inoculation. Some farms inoculate spawn in a somewhat open environment (Fig. 7C). The inoculation environment does affect the contamination rate.



Figure 7. Cooling and inoculation **A:** Conveying sterilized bags to cooling room **B:** Inoculation under aseptic environment **C:** Inoculation under open environment

Spawn run

Most shiitake farms in Thailand incubate shiitake bags for spawn running on the ground though some farms do so on shelves. Before being filled with inoculated bags, the ground of a growing house is limed to prevent green mold (Fig. 8A). The bags are incubated at 25-28℃ for 2-4 months. White shiitake mycelia grow from bottle necks where grain spawn was placed to the bottom (Fig. 8B). After being fully colonized, the shiitake bags turn brown (Fig. 8C), and they are ready for fruiting induction when browning is completed. It takes 48-51 days for full colonization by shiitake mycelia in the bags and 114-118 days until fruiting initiation after inoculation.



Figure 8. Spawn run **A:** Limed ground before laying bags to prevent green mold **B:** Mycelial growth from top to bottom **C:** Browning

Primordial induction

The bags are exposed to lower temperatures and higher humidity to induce fruiting. The bags are opened by removing the plastic necks and the upper part of the bag is cut (Figs. 9A and B). And then the bags are inverted on wet ground for 2-3 days. Because the ground has more moisture and is of a lower temperature, the shiitake mycelia in the bags experience a sudden change of temperature and moisture. They are turned upright again after 2-3 days (Fig. 9C). The bags are covered with wet sacks, followed by a watering in order to wet the bags thoroughly. In winter with relatively low temperatures, fruiting is induced by keeping the bags at 18-25℃ and in 90-100% humidity under plastic sheet or wetted sacks for 3-4 days. In summer, water in a bucket is cooled to 7-10℃ by adding ice, and then this cold water is used to provide a low temperature shock. Alternatively, small pieces of ice are sprinkled on top of the bags and the bags are covered with wetted sacks for 3-4

days. Some farms stimulate fruiting by beating the top of substrate with a sandal after cutting the upper plastic bags, and then providing lower temperature and high humidity as described above (Fig. 9D).



Figure 9. Primordial induction **A:** After getting rid of neck and ring **B:** Cutting top of plastic bags **C:** Brownish surface **D:** Beating the top of the substrate

Fruiting and harvesting

When small white primordia appear, the sacks are removed and the bags are watered 2-3 times per day. Shiitake is very sensitive to the level of CO₂ during fruiting, and the formation and development of fruiting bodies is inhibited by high concentrations of CO₂. Poor ventilation during fruiting body development causes the elongation of stems and slows cap enlargement. Watering is not recommended 6-12 hours before harvest. Growers allow the fruiting bodies to grow until the edge of caps partly separate from the stems. After the first flush, the substrates rest for 7-14 days and then the next flush is induced again by repeating the stimulation. Usually 3-5 flushes are harvested, with an average of total yield of about 100-150g per bag, over the course of 2~3 months. The harvested shiitake is trimmed, graded, and packed, and then preserved under cool



Figure 10. Fruiting and harvesting **A:** Watering **B:** Fruiting body growing **C:** Grading before packaging

conditions that can be as low as 7°C. Shiitake can be kept fresh for about one week under these conditions. Fresh shiitake is much preferred to dried in Thailand, so it is very important to preserve the freshness of the shiitake. The shelf life of shiitake can be extended by wrapping with paper before storing in a refrigerator.

Pathology considerations

Outbreaks of pests and diseases can be extremely damaging, especially if contamination occurs early in the cropping cycle. To maintain pest and disease-free farms, farm hygiene must be maintained. It is crucial that bags are properly sterilized and growing houses are properly managed so as to avoid unnecessary introduction of contaminants to the growing houses. Even the smallest flies and gnats as well as contaminated bags must be removed as quickly as possible. After harvesting 3-5 flushes, the weight of the substrate in a bag shrinks to 300g, the length shrinks by 1-2 inches and the yield declines to an uneconomic level. The spent substrate is recycled as an organic soil matter to gardeners and horticulturists, being given away free or sold for the very low price of THB100-200 (USD2.60-5.20) per 1.5 ton truckload (Fig. 11C).

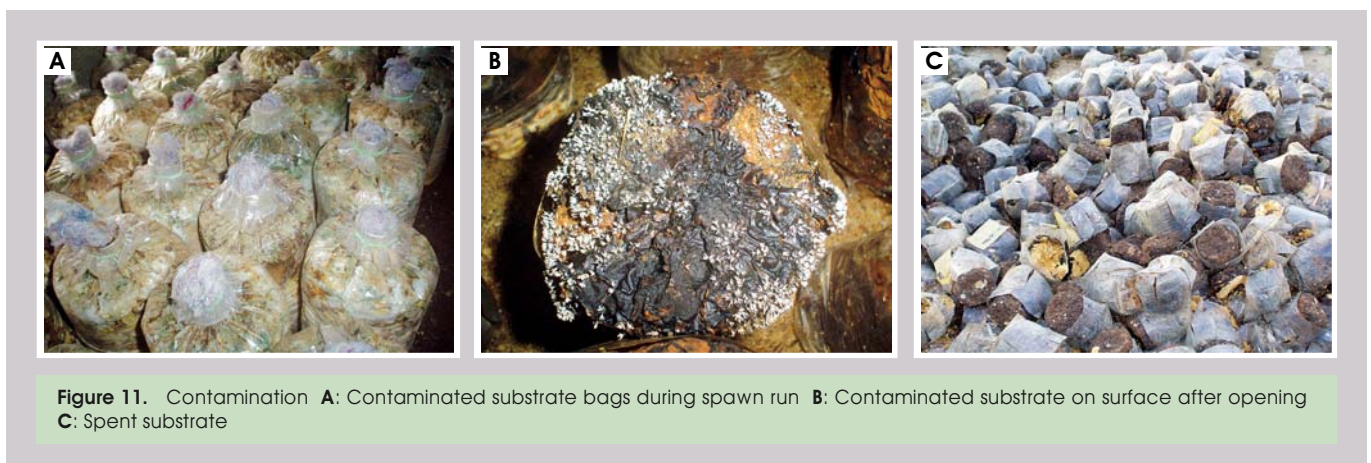


Figure 11. Contamination **A:** Contaminated substrate bags during spawn run **B:** Contaminated substrate on surface after opening **C:** Spent substrate

Shiitake Bag Supply System

How it works

Shiitake bag supply system has proven to be very effective method to support large scale shiitake cultivation as a group. Figure 12 shows how this system works. The bag supplier provides inoculated bags to its members and the bags are colonized by shiitake mycelia and produce fruiting bodies on the members' farms. Harvested shiitake from many farmers is

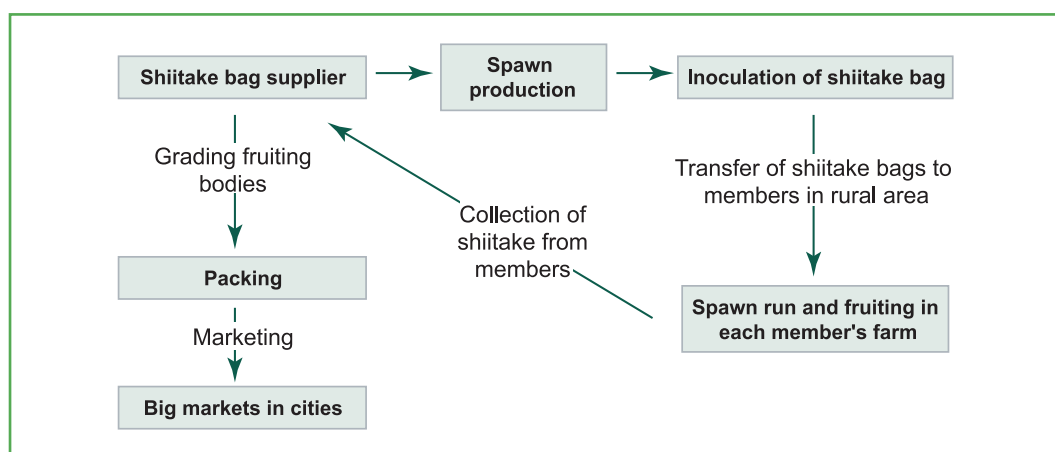


Figure 12. Operating system of shiitake bag supply

brought to the supplier, and then the supplier grades, packs, and markets the products to customers in the large urban areas.

The constant availability of fresh shiitake is a prerequisite for becoming a supplier in any of the big markets in Thailand. Because wholesalers and retailers demand a constant supply, farmers need to group together in order that the production

from many farms may allow supplying fresh shiitake continuously. This system has benefits not available through large scale commercial farms. The growing houses in this system are owned by each farmer, so a large investment to build many growing houses is not required. Moreover, each individual farmer bears the responsibility for his or her own shiitake crops. If the shiitake bags are well managed, the farmer can earn money by selling the shiitake to the bag supplier. On the other hand, the farmer earns little if the bag culture is badly managed. In addition, scattered shiitake farms do not have the same risk of accumulated diseases and insects like a very large scale shiitake farm do. The small farmers who cultivate pre-inoculated bags also benefit by getting a quicker return of capital than if they themselves had to perform the whole process of shiitake cultivation.

Shiitake is more suitable for a central bag supply system than other mushrooms such as oyster mushrooms. The relatively high price of shiitake motivates growers to invest and join this system which gives such quick returns. The fruiting bodies of shiitake have longer shelf life than other mushrooms, and this also induces some growers to choose shiitake cultivation. There are several shiitake bag suppliers in northern Thailand. Some deliver fully colonized bags to farmers while others deliver partly colonized bags. Among them, the farm A will be illustrated below.

The farm A is a large shiitake bag supplier with about 400 members in Chiangmai. The price of a bag is THB5(USD0.13) or more, depending on the distances of the farms. The shiitake bags are delivered right after inoculation in winter, but delivered when shiitake mycelia cover the top of the bags in summer. This is because summer creates a higher risk of contamination. The farm A produces about 4,000 bags per cycle, which takes 3 days, from September to February (more or less winter), and about 1,000 bags per cycle from March to August (summer) (Figs. 13).



Each member incubates the delivered shiitake bags for spawn run and produces shiitake on his or her own farm. They send their harvested shiitake to the bag supplier. The farm A collects about 120kg per day in winter and about 50kg per day in summer. This amounts to 3.6 tons per month in winter and 1.5 tons per month in summer. The collected shiitake is trimmed, graded, and packed, and then delivered to the big markets in Chiangmai, Lampang, and Bangkok (Figs. 14). The

price of shiitake fluctuates, and at one time the retail price of shiitake was as low as THB100 (USD2.60) per kg due to the presence of quantities imported shiitake from China. In general, shiitake from the farm A is sold at THB100-120 (USD2.60-3.12) per kg to wholesalers in the nearby provinces.



Figure 14. Postharvest at bag supplier's place **A:** Trimming and grading collected shiitake **B:** Shiitake packing

Cost and benefit

For farm A (shiitake bag supplier)

Table 2. Cost for one bag production

Item	Cost in THB
Sawdust	1.00
Supplement	0.5
Plastic neck	0.25
Plastic bag*	0.35
Labor for filling and packing**	0.50
Depreciation cost of equipments	0.50
Transportation	0.40
Others***	0.50
Total	4.00 (USD0.10)

* Polyethylene plastic bag 1kg cost THB75 (USD1.935) has approximate 200 bags

** One man day labor cost THB140, can fills and packs the bag 400 bags (skilled person) and 200-300 bags (non skilled)

*** Rubber band, spawn, fuel for sterilization water, and electrical power

It costs THB4 (USD0.10) for the farm A to produce an inoculated shiitake bag to be delivered to its members. This cost includes substrate materials, plastic bags and necks, labor, depreciation cost, transportation, and other costs (Table 2).

One cycle of bag production takes 3 days: one day for sawdust preparation and filling bags, the second day for sterilization and cooling, the last day for inoculation. This process can be repeated ten times a month. During a winter of 6 months, 4,000 bags are produced by the three day long process. The contamination rate is 10% in winter, so 400 contaminated bags are removed before the rest are delivered to member farms. In addition, some bags are broken during delivery and some bags are contaminated in the member farms and the farm A doesn't charge for these bags. This loss reaches 10% of the delivered bags (360 bags), so it should be calculated that farm A delivers 3,240 bags in one cycle (3 days) and 32,400 bags a month. Therefore, 194,400 bags are sold to member farms over the course of the winter.

Only 1,000 bags are produced per cycle in summer. The contamination rate reaches up to 15% (150 bags) in summer, but additional loss during and after delivery is only 5% of the delivered bags (42.5 bags). It can be calculated that 807.5 bags are delivered by one operation and 8,075 bags a month. Therefore, 48,450 bags are sold to member farms for the whole summer. As a result, the farm A delivers 242,850 bags in the course of one year (Table 3).

Table 3. Volume of shiitake bag delivery to member farms per year

	Volume of production per operation (3days)	Volume of production per year	Unusable bags	Sold bags
Summer (6 months)	1,000 bags	60,000 bags	11,550 bags	48,450 bags
Winter (6 months)	4,000 bags	240,000 bags	45,600 bags	194,400 bags
Total		300,000 bags	57,150 bags	242,850 bags

The bags are sold to the members for THB5 each, so the net profit from selling a bag is THB1 because production cost of a bag is THB4 (Table 2). Therefore, the farm A makes a net profit of THB242,850 (USD6,314.3) by selling 242,850 bags per year.

Upon receiving the shiitake, the farm A pays to the member farms THB70 (USD1.82) per kg. A shiitake bag produces average 120g of shiitake, so the sold 242,850 bags in member farms produce 29,142kg per year. The farm A pays THB2,039,940 (USD53,040) to member farms in a year. The sale price of collected shiitake to markets varies according to quality. Shiitake is graded into four grades and the price varies from THB60 to 120 (USD1.56-3.12) according to the grades. When calculated by proportion and price per kg of each grade, the farm A earns THB2,914,200 (USD75,772.2) per year by supplying shiitake to markets (Table 4).

Table 4. The value of shiitake sale to market per year

Grade	Diameter (cm)	Proportion (%)	Yearly production (kg)	Price per kg in THB	Yearly value of sale in THB
A	> 3.5	20	5,828.4	120	699,408
B	2.5-3.4	40	11,656.8	110	1,282,248
C	1.0-2.5	20	5,828.4	100	582,840
D	< 1.0	20	5,828.4	60	349,704
Total		100	29,142		2,914,200 (USD75,772.2)

Transportation costs are THB5 for 1kg shiitake, so the farm A pays THB145,710 (USD3,788.6) per year as the transportation cost. The net profit of farm A from supplying shiitake to markets is THB728,550 (USD18,943.1). In conclusion, the net profit of the farm A from supplying both shiitake bags to member farms and selling shiitake to the markets reaches THB971,400 (USD25,257.4) per year (Table 5).

Table 5. Cost and benefits of shiitake bag supplier, farm A

<p>1. From shiitake bag supply to member farms</p> <ul style="list-style-type: none"> • Income from supplying a bag: THB5 • Cost for producing a bag: THB4 • Profit from supplying a bag: THB1 • Net profit of selling bags for a year: THB1 × 242,850 bags = THB242,850 (USD6,314.1)
<p>2. From shiitake supply to markets</p> <ul style="list-style-type: none"> • Total value of sale: THB2,914,200 (USD75,772.2) • Transportation costs: THB5 × 29,142kg = THB145,710 (USD3,788.6) • Farmer payments: THB70 × 29,142kg = THB2,039,940 (USD53,041) • Net profit = Total value of sale - Transportation costs - Farmer payments = THB2,914,200 - THB145,710 - THB2,039,940 = THB728,550 (USD18,943)
<p>3. Total Net Profit</p> <p>net profit of bag supply + net profit of shiitake sale = THB242,850 + THB728,550 = THB971,400 (USD25,257.4)</p>

For the members farms

The member farms buy shiitake bags from the farm A at THB5 per bag. The amount of delivered bags varies from 5,000 bags to 10,000 bags per crop depending on the available capital of each farm. If a member farm purchases 10,000 bags per crop, it pays THB50,000 (USD1,300) per crop. The construction cost for a growing house which can contain 10,000 bags is about THB20,000 (USD520) and the house will last for 3-4 years. Most farms cultivate two crops a year though some in highlands cultivate three crops. Therefore, the house depreciation cost is about THB3,333 (USD86.66) per crop. The labor costs for bag management and harvest reaches THB12,000 (USD312) for a crop and other expenses such as water, electricity, and so on are THB300 (USD7.8). Therefore, the total production cost is THB65,633 (USD1,706.53) for a crop (Table 6).

A shiitake bag produces average 120g, so a delivery of 10,000 bags produces 1,200kg for a crop. A member farm is paid by THB70 for 1kg shiitake, and it can earn THB84,000 (USD2,184) for a crop. The net profit of a member farm is THB18,367 (USD477.56) for a crop (Table 7). However, most farms pay their own labor without employing workers. In that case, the net profit per crop reaches THB30,367 (USD789.57). In conclusion, the yearly net profit of a member farm is at least THB36,734 (USD955.12) and at most THB60,734 (USD1,579.15) for cultivating two crops (Table 7) per year.

Table 6. Production cost for a member farm per crop

Item	Unit price in THB	Number of units	Cost in THB
Shiitake bags	5	10,000 bags	50,000
A growing house containing 10,000 bags	20,000	it lasts for 3 years and two crops are cultivation a year	3,333
Labor cost	12,000		12,000
Others	300		300
Total			65,633 (USD1,706.53)

Table 7. Cost and benefit of a member farm

<p>1. Production cost per crop Including labor cost: THB65,633 (USD1,706.53) Excluding labor cost: THB53,633 (USD1,394.51)</p>
<p>2. Value of shiitake sale per crop Volume of shiitake sale: 120g × 10,000 bag = 1,200kg Value of shiitake sale: 1,200kg × THB70 = THB84,000 (USD2,184)</p>
<p>3. Net profit per crop when workers are employed, Net profit = Value of sale - production cost (including labor cost) = THB84,000 - THB65,633 = THB18,367 (USD477.56) when family labor is used, Net profit = Value of sale - production cost (excluding labor cost) = THB84,000 - THB53,633 = THB30,367 (USD789.57)</p>
<p>4. Net profit per year Minimum: THB36,734 (USD955.12) - when workers are employed Maximum: THB60,734 (USD1,579.18) - when family labor is used</p>

According to Office of the National Economic and Social Development Board in Thailand, the average income per capita in rural areas is THB916 (USD23.82) per month and THB10,992 (USD285.80) per year. When it is assumed that a family has 4 members, the average income per family in rural area is THB43,968 (USD1,143.21) per year. The income source for shiitake growers is the value of shiitake sale to bag supplier and their yearly income reaches THB168,000 (USD4,368) for cultivation two crops. Therefore, it can be said that a shiitake cooperative member farm makes more money than an average rural family.

Conclusion

Shiitake can be easily cultivated in northern Thailand with relatively low costs and low technology. However, a high yield and high quality requires that farmers have more experience in shiitake cultivation. Communities in the northern region of Thailand can capitalize on their relatively cheap home labor by encouraging more shiitake production. The additional income from shiitake growing can further improve a farmer's standard of living. Clearly, the establishment of a properly organized mushroom growing industry is a vital component of the rural development programs in Thailand.

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