# Final Report of PGTF Project

**Project title:**

Enhancing capacities in India, Myanmar, Nepal and China to achieve sustainable agriculture and improved livelihoods through the development of mushroom farming

(Project code: INT/21/K05)

**Implementation Institution:**

Centre for Mountain Futures (CMF), Kunming Institute of Botany, Chinese Academy of Sciences

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# Contents

## Summary

Global mushroom consumption has risen significantly in recent years, creating growing demand for both wild and cultivated varieties as research over the past thirty years has demonstrated their nutritional benefits and immune-boosting properties. Recognizing this potential, mushroom cultivation has emerged as an effective tool for rural development, offering sustainable income opportunities and improved nutrition for impoverished communities.

The Centre for Mountain Futures (CMF) at the Kunming Institute of Botany, Chinese Academy of Sciences, has successfully implemented this project across mountainous regions in China, India, Nepal, and Myanmar. By combining scientific innovation with traditional knowledge, the initiative has trained local farmers and technicians in advanced cultivation techniques, including spawn production, substrate preparation, and contamination control. Converting agricultural waste into valuable mushroom products has boosted household incomes while promoting environmental sustainability. This project establishes a replicable model that enhances livelihoods while conserving ecosystems, proving mushroom cultivation's potential as a nature-based solution for vulnerable mountain communities.


# 1. Project Implementation Background

Mushrooms have long been valued as both a nutritional and medicinal resource, offering high-quality proteins, essential amino acids, dietary fiber, and beneficial bioactive compounds including antioxidants and immune-boosting substances. With over 3,000 known edible species worldwide, mushrooms present remarkable diversity in flavor, texture, and nutritional profile, making them an ideal food source for enhancing food security. Their unique ability to be cultivated sustainably with minimal inputs or harvested from wild ecosystems at low cost creates valuable opportunities to improve rural livelihoods while supporting environmental conservation.

The global mushroom market has shown consistent growth, reaching 12.74 million metric tons in consumption during 2018 according to FAO data, with Asian markets accounting for about 80% of total demand. Projections indicate this figure will rise significantly to 20.84 million tons by 2026, revealing substantial potential for rural economies to engage in this expanding sector. This growth trajectory positions mushroom cultivation as a promising avenue for economic development in agricultural communities.

Mushroom farming represents an innovative approach to sustainable agriculture, offering multiple environmental and economic advantages that align with climate-smart development strategies. Unlike conventional crops, mushroom cultivation requires minimal land area, can operate year-round in controlled environments, and generates income more rapidly than many traditional agricultural activities. A key benefit lies in its circular production model, where agricultural byproducts and waste materials are transformed into valuable growing substrates. After harvest, the spent substrate can be repurposed as organic fertilizer, creating a closed-loop system that enhances overall farm productivity while addressing waste management challenges.

These characteristics make mushroom cultivation particularly suitable for implementation in India, Myanmar, Nepal, and China, where smallholder farmers commonly face challenges including poverty, food insecurity, limited market access, and environmental pressures. Each country presents distinct opportunities and constraints for mushroom production that require tailored intervention strategies.

In India, current efforts focus on practical, field-based training covering essential aspects such as spawn production, substrate preparation, and post-harvest processing. The program incorporates study visits to successful commercial operations to demonstrate viable business models, while strategic partnerships with local institutions help ensure training content addresses regional specificities and builds sustainable technical capacity. A primary objective is to improve cultivation precision, particularly in contamination control and spawn quality management, ultimately empowering rural communities to participate effectively in global mushroom markets while enhancing household nutrition and environmental sustainability.

Myanmar faces more fundamental challenges in mushroom development, including widespread poverty, limited agricultural extension services, and recurring incidents of mushroom poisoning due to insufficient public knowledge about edible varieties. Despite these constraints, the country's mountainous terrain and forest resources could potentially support substantial mushroom production. In response, capacity-building efforts initiated by CMF have included training workshops to equip farmers with essential cultivation skills.

Nepal's mushroom sector is more developed than Myanmar's, with over 6,000 registered producers, primarily in the Kathmandu Valley. Farmers commonly cultivate oyster, button, and shiitake mushrooms, but technological constraints limit production to a narrow range of species. The decline in wild mushroom harvesting, driven by reduced forest access and fading traditional knowledge, further underscores the need for sustainable cultivation alternatives. However, inadequate growing facilities prevent farmers from scaling up production or diversifying into new species. To address these gaps, our training programs focus on introducing high-potential mushroom varieties, advanced cultivation methods, and reliable spawn production techniques to strengthen the sector's resilience and productivity.

China's mushroom sector benefits from steadily growing domestic consumption and sophisticated production systems. Innovative cultivation technologies developed specifically for rural implementation have demonstrated success in transforming unproductive land into valuable agricultural assets, particularly in Yunnan province. As consumer demand expands for varied, high-quality mushroom products, research efforts are increasingly focused on domesticating additional macrofungal species with potential commercial value. These developments align closely with China's broader Rural Revitalization Strategy, which emphasizes sustainable livelihood options for rural communities. Across all countries, mushroom cultivation initiatives aim to deliver multiple benefits including poverty reduction, improved nutrition, environmental sustainability, and enhanced market access for smallholder farmers.

# 2. Project Progress and Results

## 2.1 Advanced Mushroom Cultivation Training for Indian Technicians

The CMF team has conducted specialized training programs on the cultivation of Oyster mushrooms (*Pleurotus ostreatus*) and Leshi mushrooms (*Ganoderma spp*.) for agricultural technicians in India. The training focuses on 1) Contamination control – ensuring sterile techniques to improve yield and quality; 2) Optimized cultivation methods – Enhancing substrate preparation, inoculation, and growth monitoring.

To achieve optimal production, four key environmental factors: temperature, humidity, ventilation, and illumination must be carefully managed.

***For temperature control:***

Greenhouse Temperature Management

- Summer greenhouse range: 22-30°C
- Winter greenhouse range: 12-21°C

Species Temperature Categories

Summer Strains (22-30°C):

- Yellow Oyster (*Pleurotus citrinopileatus*)
- Black Oyster (*Pleurotus ostreatus var. florida*)
- Pocket Oyster (*Pleurotus pulmonarius*)
- Shiitake (*Lentinula edodes*)
- Jelly Muer (*Auricularia cornea*)

Winter Strains (12-21°C):

- Enoki (*Flammulina velutipes*)
- King Oyster (*Pleurotus eryngii*)
- Chestnut Mushrooms (*Pholiota nameko*)
- Lion's Mane (*Hericium erinaceus*)
- Black Muer (*Auricularia heimuer*)

***Contamination Management Protocol***

Proper contamination handling requires strict protocols. For contaminated cultures in glass petri dishes, autoclaving must be performed prior to disposal, after which the sterilized media can be safely buried or repurposed as horticultural compost. In cases where plastic petri dishes are contaminated, they should similarly undergo autoclave sterilization before being discarded along with polypropylene (PP) bags. This two-tiered waste management approach ensures complete biological decontamination while promoting environmentally responsible disposal practices for both glass and plastic laboratory materials. The procedure maintains biosafety standards while aligning with sustainable waste management principles through either soil incorporation of sterilized organic media or proper disposal of treated plastic waste.

1) **Autoclaving Standards**
    - Sterilize all contaminated materials at 121°C for 30–60 minutes
    - *Note*: Remove Parafilm before autoclaving
2) **Glass Petri Dishes**
    - After autoclaving:
      → Wash thoroughly
      → Dry completely
      → Dry-sterilize before reuse
3) **Spawn Bottles**
    - Autoclave contaminated bottles
    - Discard media by either:
      → Burying far from lab/growing areas
      → Cautiously using in horticultural compost (*risk of green mold spread*)
    - Reuse bottles after washing
4) **Contaminated Bags in Incubation**
    - Non-green mold contamination:
      → If mycelium covers ≥50%, isolate for potential fruiting
    - Full contamination:
      → Remove immediately
      → Bury or compost media
5) **Growing House Management**
    - Minor contamination:
      → Excise with sterile scalpel + 100% alcohol
    - Severe contamination:
      → Use heat-sterilized tools (knife/scissors)
      → Cut away contaminated sections
      → *Re-sterilize tools between each use*
    - Pleurotus spp. bags: Can be buried or reintroduced post-decontamination
6) **Reusable Components**
    - Clean and sterilize: Bottle caps/necks, and all tools after every use

**Key Safety Notes**:
✓Always prioritize **heat sterilization** of tools

✓ Isolate questionable materials to **prevent cross-contamination**
✓ Monitor compost for **green mold resurgence**

This protocol ensures biosafety while maximizing resource efficiency through reuse/recycling where viable.

*Prof. Peter Mortimer (CMF/KIB) evaluates suboptimal growing conditions in a traditional mushroom cultivation structure during a field assessment in Nagaland, India, identifying key areas for technical improvement to enhance productivity.*

*Prof. Peter Edward Mortimer (CMF/KIB) examines an insect pest infestation affecting Pleurotus ostreatus cultivation in Meghalaya, India, while advising local farmers on integrated pest management solutions.*

## 2.2 Adaptive Mushroom Cultivation Training for Myanmar

To adapt to pandemic restrictions, the CMF team transitioned to digital platform to deliver mushroom cultivation training for Myanmar farmers and technicians, providing detailed guidance on species selection, cultivation techniques, and market-oriented production. Following the pandemic, CMF complemented these online efforts with hands-on training sessions covering essential practices such as pest management, substrate preparation, spawn inoculation, and environmental control throughout the production cycle, while also addressing post-harvest handling and value-added product development to maximize income potential. To sustain knowledge sharing, CMF established a farmer-focused social media platform in Chin State, Myanmar, creating virtual communities for ongoing cultivation advice and peer-to-peer learning.

This integrated approach - combining digital and in-person training - ensured continuous capacity building while adapting to changing circumstances, ultimately strengthening Myanmar's mushroom sector through accessible, practical knowledge transfer. The social media initiative in particular has fostered long-term connections among farmers, enabling real-time problem solving and best practice sharing beyond formal training periods.

***Hands-on Spawn Production Training***

A technical training session on mushroom spawn production was conducted in Myanmar, equipping local farmers and technicians with practical skills for high-quality spawn preparation. Participants learned essential techniques including:

- Sterile culture transfer methods
- Grain substrate preparation and sterilization
- Inoculation protocols under aseptic conditions
- Quality control measures for spawn storage

Meanwhile, integrated pest management and liquid media preparation for mushroom cultivation have been also introduced.

The training emphasized **low-cost, adaptable technologies** suitable for Myanmar's rural contexts, enabling participants to establish independent spawn production units. This capacity-building initiative addresses a critical bottleneck in Myanmar's mushroom value chain, reducing dependence on imported spawn while improving local production standards.

*A model mushroom growing house in Tonzang Village showcases high-yield Pleurotus Ostreatus cultivation after CMF's technical intervention in Chin State, Myanmar.*

***Integrated Pest Management for Mushroom Cultivation***

Effective pest control in mushroom farming relies primarily on preventive measures to maintain a clean and protected growing environment. Key strategies include:

1) **Structural Protection**
    - Install 1mm mesh netting on ventilation openings to allow airflow while blocking insects
    - Implement double-door systems to create entry barriers
    - Ensure proper sealing of all potential entry points
2) **Sanitation Protocols**
    - Remove mature mushrooms promptly to prevent over-ripening
    - Eliminate mushroom debris and rotten specimens immediately
    - Prevent water accumulation in/around growing bags
3) **Targeted Control Methods**
    - Use yellow sticky traps for sciarid fly monitoring and control
    - Apply ant repellent around shelving legs and infrastructure
    - Maintain optimal harvest timing to reduce pest attractants

4) **Environmental Management**

- Ensure proper air circulation to discourage pest colonization
- Control humidity levels to avoid excessive moisture retention

Proactive prevention through these integrated measures significantly reduces pest pressures while minimizing the need for reactive interventions.

*Farmers in Myanmar practice spawn production techniques during a hands-on training session*

***Liquid Media Preparation***

1) **Media Selection:** Various liquid media formulations are available for mushroom culture, including:

- Yeast Mannitol Broth
- Sabouraud Dextrose Broth (SDB)
- Malt Extract Broth (MEB)
- Potato Dextrose Broth

*Note*: Media selection should align with the specific nutritional requirements of the target mushroom species.

2) **Materials & Equipment**

- **Consumables:**
  - Conical flask (250 mL recommended)
  - Cotton/aluminum foil or foam cork for sealing
  - Sterile surgical blades
- **Chemicals:**
  Selected broth media (e.g., 30 g SDB per liter), distilled water, and mushroom culture (agar plugs)
- **Equipment:** Autoclave, Laminar flow hood, Precision scale, Orbital shaker

3) **Step-by-Step Procedure**

- **Media Preparation**
  - Measure 4.5 g SDB (for 150 mL in 250 mL flask)
  - Add 150 mL distilled water and mix thoroughly until fully dissolved
  - Seal flask with cotton + aluminum foil or foam cork
- **Sterilization**
  - Place media in PP bag and autoclave at 121°C for 60 minutes
  - Concurrently, UV-sterilize laminar flow hood for 30 minutes
- **Inoculation**
  - Cool autoclaved media in laminar hood (1 hour, blower optional)
  - Aseptically transfer 5-10 mycelial agar plugs (2×2 mm) into flask
  - Re-seal and label with strain name + date
- **Incubation**
  - Place on orbital shaker at 130-150 rpm
  - Culture for 7-10 days until:
    - ✓ Initial "puffer fish" mycelial mass forms
    - ✓ Fragments into 3-5 mm pellets (ready-to-use inoculum)

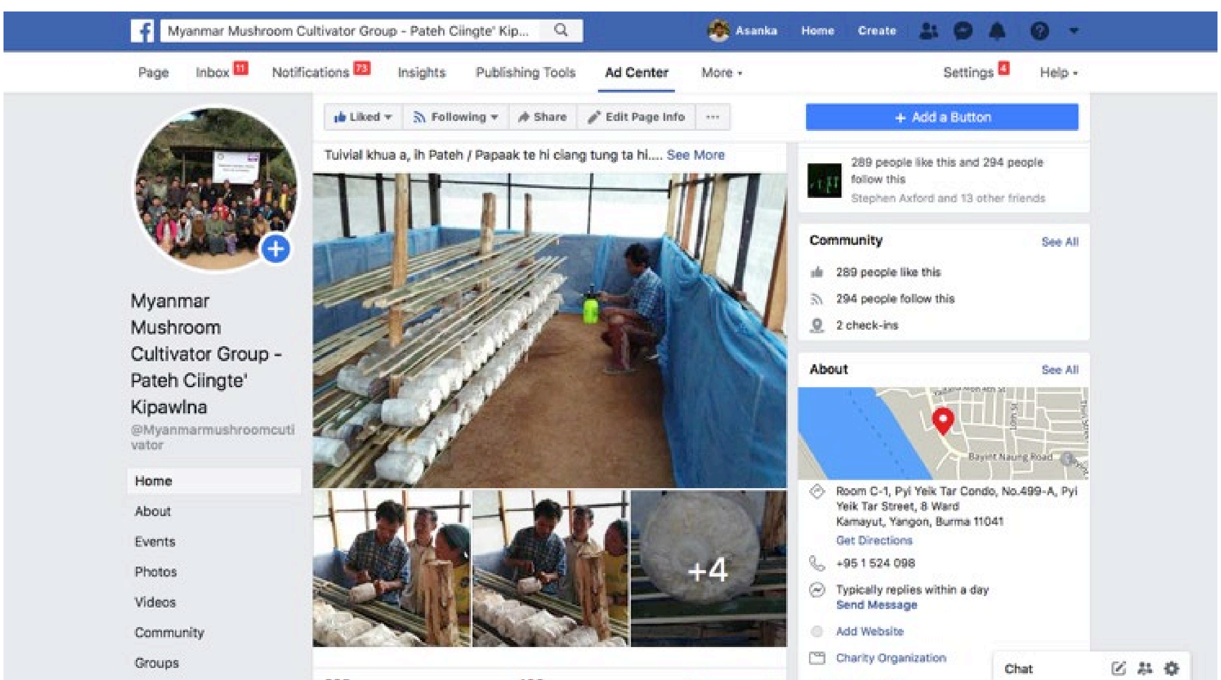
**4) Key Technical Notes**

- Maintain strict aseptic technique throughout
- Optimal flask fill: 60-80% capacity (150-200 mL in 250 mL flask)
- Pellet size indicates culture vitality – adjust rpm if needed
- Store active cultures at 4°C for short-term preservation

This protocol standardizes liquid inoculum production for efficient spawn multiplication.


*Mushroom farmers in Chin State, Myanmar practice Pleurotus Ostreatus (oyster mushroom) cultivation under the technical guidance of CMF experts, demonstrating proper substrate preparation and greenhouse management techniques.*


*Fresh and dried Pleurotus ostreatus (oyster mushroom) products at a local market in Myanmar, showcasing the growing commercial potential of mushroom cultivation in the region.*




*Screenshot of CMF's farmer-focused social media initiative in Chin State, Myanmar - creating virtual communities for mushroom cultivation advice.*

## 2.3Field Training in Mushroom Cultivation Techniques in Nepal

A team of experts from CMF, including Dr. Yuwei Hu and Dr. Asanka Bandara, conducted specialized mushroom cultivation training at the Living Mountain Lab of ICIMOD in Godawari, Kathmandu. The program focused on building local capacity through hands-on training in advanced mushroom production techniques while establishing critical infrastructure for long-term development.

The initiative established three key facilities to support mushroom cultivation: a fully equipped breeding laboratory for spawn production, a functional greenhouse for cultivation trials, and field demonstration sites showcasing forest-fungi fruiting techniques. These facilities provide farmers with practical examples of both controlled environment and forest-based production systems.

The training program covered all aspects of laboratory operations, from basic sterile techniques to advanced spawn production methods. Through practical demonstrations and supervised practice, the CMF experts ensured that local technicians developed the skills needed to independently manage all laboratory processes. This knowledge transfer enables sustainable local capacity for producing high-quality mushroom spawn, reducing dependence on imported materials and strengthening mushroom value chain from production to market.

***Learning mushroom cultivation techniques: Lab establishment***

The CMF team guided local technicians in assembling a comprehensive spawn production facility. The lab was outfitted with essential equipment including laminar flow hoods for sterile work, autoclaves for media sterilization, incubators for culture growth, and precision tools for inoculation work. Critical materials were provided for spawn production, including various culture media, grain substrates, sterile containers, and protective equipment to maintain aseptic conditions.


*Essential materials and equipment for establishing a mushroom cultivation laboratory in Kathmandu, Nepal, including laminar flow hoods, autoclaves, and substrate preparation tools.*

***Learning mushroom cultivation techniques—hands-on mushroom cultivation***

Our team conducted comprehensive hands-on training in mushroom cultivation techniques at the Godawari site in Kathmandu, Nepal. The program covered the complete production cycle through seven key operational stages:

- **Culture Isolation**: Trainees learned sterile techniques for obtaining pure cultures from mushroom tissue samples
- **Subculture**: Participants practiced transferring cultures to fresh media for strain maintenance
- **Spawn Preparation**: Instruction included preparing grain spawn using sterilized rye and wheat substrates
- **Substrate Bagging**: Farmers were trained in proper filling and sealing of cultivation bags
- **Inoculation**: Hands-on practice in aseptic transfer of spawn to prepared substrates
- **Incubation**: Management of environmental conditions for mycelial colonization
- **Fruiting**: Techniques for inducing and maintaining optimal mushroom production conditions

The training focused on four commercially valuable species:

- Golden oyster mushroom (*Pleurotus citrinopileatus*)
- Phoenix oyster mushroom (*Pleurotus pulmonarius*)
- King oyster mushroom (*Pleurotus eryngii*)
- Shiitake (*Lentinula edodes*)

Through this practical training approach, trainees gained complete technical capacity - from laboratory culture work through final fruiting body production - enabling them to establish independent mushroom cultivation enterprises. The inclusion of multiple species provides farmers with options to select varieties best suited to their local market conditions and production capabilities.

*CMF experts teach local technicians critical mushroom farming skills, from lab protocols to growing house management*


*CMF experts lead a hands-on mushroom cultivation training session in Kathmandu, Nepal, demonstrating advanced techniques to local technicians and farmers.*

***Learning mushroom cultivation techniques—compost based mushroom cultivation***

We implemented two specialized training programs on compost-based mushroom cultivation, an innovative agroforestry approach that leverages natural forest ecosystems for sustainable mushroom production. The first training was conducted in Godavari, Kathmandu, where we established three permanent demonstration sites for wine cap mushroom (*Stropharia rugosoannulata*) cultivation under forest canopies. The second training expanded this low-input technique to Dailekh in Karnali Province, adapting the methods for high-altitude conditions and local resource availability.

These programs introduced rural farmers to a practical cultivation system requiring minimal infrastructure investment. Participants gained hands-on experience in:

- Selecting optimal forest sites for mushroom beds
- Preparing and enriching organic substrates from locally available materials
- Establishing and maintaining productive mushroom beds
- Managing microclimate conditions using natural forest cover
- Implementing sustainable harvesting techniques

The Godavari demonstration sites continue to serve as long-term training resources, showcasing how forest-based cultivation can generate income while maintaining ecological balance. In Dailekh, the training specifically addressed challenges of higher elevations, helping farmers adapt techniques to their local environment.

This approach has proven particularly valuable for remote communities, offering:

- Reduced startup costs compared to conventional cultivation
- Utilization of existing forest resources
- Minimal equipment requirements
- Enhanced food security and income opportunities
- Sustainable integration with forest ecosystems

Both training programs emphasized practical, field-based learning to ensure farmers could immediately apply the techniques in their local contexts. The methodology represents an effective model for rural development that combines traditional ecological knowledge with modern mycological techniques.

*CMF experts demonstrate compost-based wine cap mushroom (Stropharia rugosoannulata) cultivation techniques during a hands-on training in Godawari, Kathmandu, Nepal*

*CMF experts conduct hands-on compost-based wine cap mushroom (Stropharia rugosoannulata) cultivation training for farmers in Dailekh, Karnali Province, Nepal, demonstrating sustainable techniques using local agricultural waste.*

***Learning mushroom cultivation techniques—management and mushroom harvest***

We conducted comprehensive capacity-building training on advanced mushroom cultivation management and harvesting techniques in Kathmandu, Nepal, covering all critical technical aspects of the production cycle. The program specifically addressed greenhouse operations and fruiting management, focusing on optimizing primordia formation by troubleshooting delayed fruiting in substrate bags.

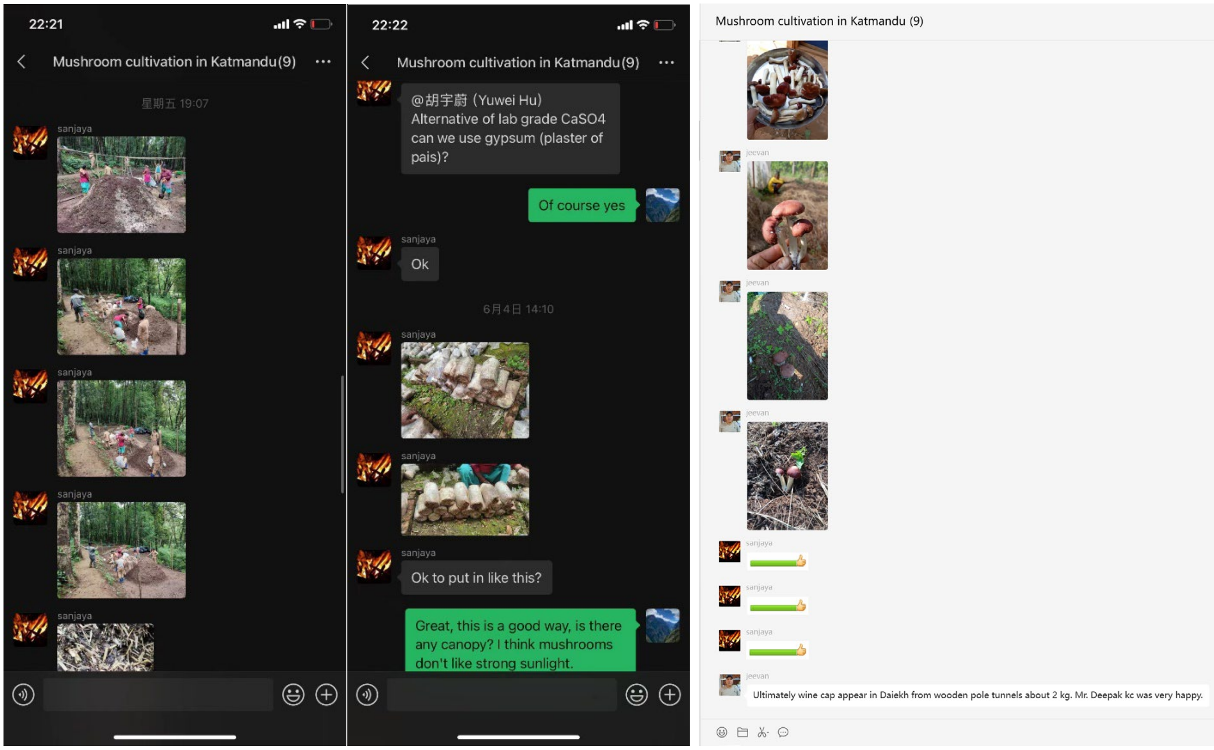
Participants received hands-on instruction for precise greenhouse environmental control, including the timing of opening and closing plastic sheeting on both sides to regulate daily temperature fluctuations. Specialized training was provided for King oyster mushroom production, teaching farmers selective primordia management techniques where only 1-3 fruiting bodies are maintained per substrate to enhance product quality. The curriculum also included practical sessions on inoculation methods, proper bagging procedures, autoclave operation protocols, and specialized watering techniques adapted for forest floor cultivation systems.

*Integrated mushroom cultivation training in Nepal: CMF experts demonstrate greenhouse management for non-compost species (right) alongside field techniques for compost-based cultivation (left), showcasing adaptable production methods.*

***Digital Knowledge Sharing Platform for Mushroom Cultivation***

To enhance knowledge dissemination and technical support, we established an innovative digital learning platform using WeChat to facilitate continuous education and problem-solving for mushroom farmers. This interactive communication channel serves as a 24/7 support system for cultivation management.

Our digital platform provides real-time technical support by offering immediate troubleshooting solutions for cultivation challenges, with experts guaranteeing responses to farmer queries within 24 hours through case-based problem solving tailored to specific issues. The platform facilitates continuous knowledge sharing by distributing daily cultivation tips and best practices, sending seasonal management reminders, and providing visual guides including photos and videos of technical procedures. This comprehensive approach ensures farmers receive timely, practical support throughout their mushroom cultivation journey while fostering a collaborative learning community.




*A WeChat group has been set up and used for mushroom cultivation techniques communication among CMF team and technicians from Godawari, Kathmandu, Nepal.*

## 2.4 Advancing Mycological Innovation: High-Value Mushroom Cultivation and Cross-Border Collaboration in China

***Bridging Innovation and Tradition: High-Value Mushroom Cultivation in Rural Yunnan.***

We introduced advanced cultivation techniques for high-value mushroom species in China's rural communities through targeted training programs in Honghe, Yunnan. While China possesses relatively developed mushroom cultivation technologies compared to other developing nations, rural areas still face significant challenges including limited access to robust mushroom strains and insufficient funding for production facilities. Our initiative specifically addressed these gaps by introducing two premium mushroom varieties - the wine cap mushroom (*Stropharia rugosoannulata*) and the black wood ear mushroom (*Auricularia heimuer*) - coupled with comprehensive cultivation training.

***Cross-Border Collaboration: Strengthening Mycological Research Under the Belt and Road Initiative***

We have established ongoing collaborative exchanges between Chinese research institutions and Southeast Asian partners as an integral component of China's Belt and Road Initiative. This international cooperation takes multiple forms, including jointly organized symposiums, specialized training programs, and collaborative field research expeditions. The initiative facilitates vital knowledge exchange and capacity building in mycological research and fungal conservation between China and Southeast Asian nations. Through these activities, we systematically share China's expertise and Yunnan's practical experience in mycorrhizal fungi research and biodiversity protection. This cooperation creates sustainable mechanisms for transnational collaboration on fungal diversity conservation while strengthening the Greater Mekong Subregion's ecological protection network. The established partnerships provide a strong foundation for future joint research initiatives at various levels and contribute significantly to regional scientific and technical advancement in mycology.

This initiative successfully bridges the gap between China's advanced mycological research and practical applications in rural development, while fostering international cooperation in fungal biodiversity conservation and sustainable utilization. The program's dual focus on local capacity building and regional knowledge sharing positions it as a model for South-South cooperation in agricultural biotechnology.


*Research seminar on mycorrhizal fungal diversity and traditional ecological knowledge during the III Mountain Future Conference, highlighting conservation and sustainable use practices*

*Sino-Thai research collaboration: Participants of the mycorrhizal fungi diversity seminar pose together after knowledge exchange on traditional utilization practices and conservation strategies*


*Field research expedition documenting mycorrhizal macrofungal diversity in the sacred Amu Mountain forests of Honghe, Yunnan, China - integrating ecological surveys with Hani ethnomycological knowledge.*

*Documenting Macrofungal Biodiversity in the Sacred Forests of Amu Mountain, Yunnan, China*

***Divine Mushrooms and Mountain Wisdom: Integrating Indigenous Knowledge and Scientific Research for Fungal Conservation.***

The Hani and Yi ethnic communities in Honghe have cultivated extensive traditional knowledge about edible mushroom utilization through generations of interaction with Amu Mountain's ecosystems. These indigenous groups have developed sophisticated resource management systems while harvesting wild mushrooms for diverse applications - from nutritional and medicinal uses to religious ceremonies and cultural practices. The Hani people particularly revere Amu Mountain as their "Divine Mountain," believing it produces sacred mushrooms with special properties. Our field research in this biodiversity hotspot revealed both the ecological significance and untapped potential of the region's fungal resources. Amu Mountain Nature Reserve's rich vegetation supports exceptional fungal diversity, yet many species remain scientifically undocumented and underutilized in local markets. Current mushroom trade in the area focuses on only a limited number of known varieties, leaving numerous edible species undervalued. Through community interviews and participatory research, we identified critical needs for: 1) Sustainable harvesting methods that preserve mycelium networks, 2) Scientific documentation and classification of fungal biodiversity, 3) Value assessment of underutilized edible species, and 4) Integration of traditional ecological knowledge with modern conservation approaches. Our findings highlight the urgent requirement for comprehensive studies on the Mekong Subregion's macrofungi to properly assess their nutritional, economic and ecological potential while developing management strategies that honor indigenous stewardship practices. This interdisciplinary approach promises to bridge scientific understanding with local wisdom, ensuring both biodiversity conservation and sustainable livelihood opportunities for mountain communities.

*Harvesting wine cap mushrooms (Stropharia rugosoannulata) cultivated alongside passion fruit vines in Honghe's dry-hot valley, Yunnan - demonstrating climate-smart intercropping for marginal lands.*

*A farmer harvests freshly grown Auricularia heimuer (black wood ear mushroom) at a sustainable cultivation farm in Honghe's arid valley, Yunnan*

# 3 Outputs and Outcomes

**Capacity Building for Sustainable Mushroom Cultivation Across Asia**

Our initiative significantly strengthened the technical capabilities of mushroom farming communities in India, Myanmar, Nepal, and China through a comprehensive capacity-building program. The project delivered:

- **Hands-on training workshops** covering advanced cultivation techniques, spawn production, and contamination control
- **Knowledge-sharing conferences and seminars** facilitating exchange between farmers, researchers, and technicians
- **Specialized skill development** in laboratory operations and modern best practices

A cornerstone achievement was the development of **detailed mushroom production guidelines** (see Annex), serving as:

- A standardized reference for sustainable cultivation methods
- A training resource for future extension programs
- A technical manual supporting quality production

These efforts have directly contributed to:

- Enhanced production efficiency and product quality
- Increased adoption of climate-smart agricultural practices
- Improved income generation opportunities
- Strengthened regional knowledge networks

The training manual represents a lasting resource that will continue to support the growth of sustainable mushroom enterprises across participating countries, aligning with broader goals of food security and rural development.

**Long-Term Impact**

The project has created a scalable model for rural development, demonstrating that mushroom cultivation can:

- Enhance food security through nutrient-rich production
- Generate eco-friendly livelihoods in marginal lands
- Strengthen climate resilience with low-input methods

Moving forward, we can pursue a two-fold strategy to further strengthen sustainable mushroom cultivation across Asia. First, we may expand our training programs to additional regions, establishing dedicated hubs to build long-term technical capacity while providing ongoing support to existing farming communities. Second, we may focus on introducing high-value medicinal mushroom varieties, developing their full cultivation protocols and value chains to create new economic opportunities.

This approach will allow us to broaden the reach of proven cultivation methods while deepening impact through premium species development - ultimately supporting rural communities in building more resilient, climate-adapted livelihoods through mushroom production.

# 4 Financial report

| Description | Budget (USD) | | Expenditure (USD) | |
|---|---|---|---|---|
| | PGTF | CMF | PGTF | CMF |
| **PERSONNEL** | | | | |
| International Consultants | 6,200 | | 6,164 | |
| National Consultant | 3,000 | | 3,057 | |
| **OFFICIAL TRAVEL** | | | | |
| International travel | 3,600 | 3,000 | 5,656 | 7,960 |
| Domestic travel | 1,000 | 4,000 | 433 | 9,938 |
| **TRAINING** | | | | |
| Other training | 4,600 | 9,000 | 5,390 | 9,102 |
| **EQUIPMENT** | | | | |
| Expendable equipment | 1,500 | 5,000 | 0 | 0 |
| Non-expendable equipment | 800 | 6,000 | 0 | 0 |
| **MISCELLANEOUS** | | | | |
| Indirect cost | 2,300 | | 2,300 | |
| Total | 23,000 | 27,000 | 23,000 | 27,000 |

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# Annex: Mushroom Cultivation Training Manual (draft)

## 1. Plan for the capacity of mushroom cultivation

Before starting mushroom cultivation, it is essential to plan the scale of your operation. Start small if you are a beginner and scale up as you gain experience. Consider the following factors:

### *1.1 Space Availability:*

Determine the size of the growing area (e.g., greenhouse, forest floor, or indoor facility). Based on the available space, we could plan the workflow.

### *1.2 Mushroom Species:*

Choose the type of mushroom you want to grow (e.g., oyster, shiitake, button, wine cap, jelly mushroom etc.), as different species have different space and resource requirements.

### *1.3 Market Demand:*

Assess the local market demand to decide which species to grow and how much to produce.

### *1.4 Budget:*

Calculate the costs of equipment, materials, and labor.

### *1.5 Time Commitment:*

Understand the time required for each stage of cultivation, from inoculation to harvest. Prepare all the necessary culture and spawn in advance.

The manual includes several steps of mushroom cultivation: culture stock and subculture, spawn production, preparing mushroom growth bags or compost, greenhouse management and Mushroom cultivation on forest floor. When planning the production volumes, requirement can be calculated based on the following ideal values. However, note that actual results may be lower in real-world scenarios:

1 agar growth media bottle (400ml): Produces 22 – 44 mycelium plates (90mm in diameter)

1 mycelium plate: Produces 30 spawn bottles (500ml)

1 spawn bottle: Produces 40 substrate bags (1kg)

1 growth media bottle: Can produce up to 26,400 substrate bags under ideal conditions.

## 2. Culture stock and subculture

### *2.1 Preparing agar medium bottles*

Background: agar growth substrate is used to produce cultures and sub-cultures of mycelia

Materials required: agar medium (PDA or MEA), water, media bottles, PP plastic bags

**Process:**

- Chose agar medium type: PDA (Potato Dextrose Agar) can be used for most mushrooms, MEA (Malt

Extract Agar) is required for some specific mushrooms

- Measure the appropriate amount of PDA or MEA powder according to the instructions on the bottle, using precision scales and a plastic weighing tray
- Thoroughly clean the cooking pot
- Measure the required amount of water and heat it to 80°C in the cooking pot
- Gradually and continuously add the PDA or MEA powder to the heated water, stirring constantly to prevent clumping
- Pour into the medium bottles, adding a bit more than the desired amount to account for contraction as the liquid cools. Close lids loosely to prevent them from blowing off in the autoclave
- Put the filled bottles in a PP plastic bag and loosely tie opening with a rubber band
- Autoclave the bagged medium buttles for 30 minutes at 121°C
- Remove agar medium bottles from auto-clave and place in water bath at 60C, until they reach that temperature

### *2.2 Preparing Agar Petri-Plates*

Background: once the agar growth medium is sterilized, it is transferred into petri-dishes, where it acts as the growth medium for the mycelia that are grown in the next step

Material and equipment: pre-prepared agar growth medium, empty petri-dishes

Transferring agar medium into petri dish:

- Take out media bottles from water bath and disinfect, place inside the laminar airflow (LAF)
- Disinfect petri dish pack, place inside LAF, cut open and remove packaging
- Open media bottle. Briefly disinfect its cap and neck
- Pour thin layer of medium into petri dish. Gentry swirl around to distribute

Take care not to swirl too forcefully – media may touch the side or the top of the petri dish, which can foster contaminations

### *2.3 Preparing mycelium sub-cultures*

Background: sub-cultures of a mycelium are prepared by placing a piece of mycelium into an agar growth media petri-dish.

Materials required: pre-prepared agar growth medium petri-plates, mycelium cultures, parafilm

Process:

- Cut up parafilm before placing it inside the LAF.
- General rule while handling culture plates – only half-open them to minimize contamination risk
- Remove parafilm from selected finished culture plate. Disinfect sides of the plate briefly with lamp, by rotating 1-2 times
- Use a bore tool to cut pieces; if unavailable, use a scalpel. Pieces should be roughly 1x1cm in size
- Pick up a piece, rotate, and drop it onto an empty agar medium plate (Multiple pieces (up to 3) can be placed in the same plate – this will increase the speed of colonization, but also increases contamination risk)
- Close the plate with parafilm, stretching it to cover the entire side
- Label the plate with the name of strain, and date of preparation
- Limit Subcultures: 3-4 times to maintain fruiting ability

### *2.4 Preparing mycelium cultures through isolation*

Background: instead of using a mycelium culture as a source, cultures can also be prepared by using small pieces of mushroom tissue, cut out of fresh mushrooms

Materials required: pre-prepared agar growth medium plates, fresh mushrooms, parafilm

Process:

- Prepare laminar airflow as described in previous steps
- Cleaning the Mushroom: Clean the mushroom thoroughly with water. Wipe the surface with an alcohol
- Cutting the mushroom, Cut the mushroom open within the LAF. Pieces can come from the inside of the stem or cap. Cut as quickly as possible to minimize contamination. Cut out a 0.5 cm square piece. Small pieces are preferable as larger pieces are more prone to contamination. Fresh Cuts: Always open and cut the mushroom fresh before extracting a piece. Do not leave it open to avoid contamination.
- Transfer to agar medium plate: use a tweezer to extract the cut piece and drop it into a fresh agar medium plate.
- Disinfect and seal plate as described in previous steps.

### *2.5 Mycelium Storage, Sub-culture Limits, contamination distinguishment in mycelium cultures*

Store plates upside down to prevent suffocation.

Temperature Storage:

Store at 4°C in petri plates for up to 1 month.

Store at 4°C in tubes for up to 1 year.

Store at -20°C in tubes for up to 3 years.

Contamination in mycelium cultures occur when operational hygiene is not properly maintained.

Contaminated cultures cannot be used for spawn production and need to be disposed in the following manner:

**For plastic petri dishes:** dispose in wastebin at safe distance for the laboratory

**For glass petri dishes:**

Correct way is put in to PP bag and sterilize using autoclave. But in this case I asked you to throw away because all are plastic plates. We will not use these plates again

## 3. Spawn production

### *3.1 Boiling and sterilizing the grain*

Background: Boiled grain serves as the initial growth medium for spawn, which is then used to inoculate either sawdust substrate, or mushroom growth bags.

Materials required: grain, pot, stove, substrate bottles

Grain Type: various types of grain can be used as growth substrate for mushroom spawn:

- Rye: Preferred for spawn production due to its nutrient density and moisture retention. Ideal grain size for mycelium colonization
- Wheat: A viable alternative to rye, nutrient-rich and widely available
- Millet: Smaller grains offer more inoculation points, potentially speeding up colonization
- Sorghum: Provides many inoculation points; used where it is more accessible
- Brown Rice: Suitable for small-scale or home production, nutritious and user-friendly.

**Boiling the Grain**

Preparation: Determine the required amount of spawn (see section 1. Planning Spawn Production for Mushroom Cultivation) and measure the corresponding grain weight. Place the grain in a pot and add twice the volume of water.

**Boiling Process:**

- Heat the grain on high until the water temperature reaches 60-70°C
- Lower the heat and maintain a gentle boil. Stir constantly to prevent uneven cooking. If over-boiled, grains may burst and spoil
- Continue boiling until grains roughly double in size. Check the grain; it should turn from white to greyish inside. Stop boiling once first grains begin to burst

**Post-Boil Handling:**

- Remove from heat and drain using a strainer for 20 minutes, turning the grain halfway through to ensure even draining of surface water. Avoid further drying to prevent desiccation
- Transfer the grain to substrate bottles once surface water has evaporated. Close lid. Seal the filled bottles in polypropylene plastic bags using a rubber band. The bags are reusable.

**Sterilization:** Autoclave the bottles for 60 minutes, ensuring they remain upright and are not stacked or laid on their sides.

Let the bottles cool down for around 8 hours before introducing mycelium. Temperatures above 38℃ can kill the mycelium.

### *3.2 Inoculating the grain*

Materials required: uninoculated grain spawn bottles, mycelium

Ensure that the grain has cooled down to room temperature, heat will damage or kill the mycelium.

Cut a piece of mycelium, as described in the section on preparing sub-cultures

Place the piece of mycelium the piece upside down on the grain in the pre-prepared spawn bottle. Disinfect and close the lid.

Place into incubator at 28C, standing upright. The gravity will help the mycelium to colonize the whole bottle. It will b ready within approximately 2 weeks.

It takes 2 weeks for fungus to colonize the entire bottle when kept at 28°C in the incubator.

Spawn storage: the grain spawn can be stored for 2 – 4 months at 0 to 4 degrees Celsius

### *3.3 Producing Sawdust Spawn*

Background: sawdust spawn is more economical than grain-spawn, and is commonly used in larger scale production. It is created by using grain spawn to inoculate the sawdust spawn.

**Materials required**: inoculated grain spawn, wheat grain, wheat bran, sawdust.

The process is similar to preparing the grain-spawn. The composition of the substrate is as follows (by weight of dry materials):

- 20% wheat grain
- 70% sawdust of hardwood trees (softwood does not work as well)
- 10% wheat bran

**The process works as follows:**

- Cook the grain as described in the section on preparing grain spawn
- Soak sawdust and wheat bran in water. Remove excess water with a strainer
- Mix all materials together, then fill into PP bottles
- Autoclave the bottles for 60 minutes, ensuring they remain upright and are not stacked or laid on their sides

Once the sawdust substrate is pre-prepared, continue with spawn production in the same manner as describe above for grain spawn. The only difference is that instead of mycelium, already inoculated grain spawn is used to inoculate the sawdust substrate.

# 4. Preparing mushroom growth bags

## *4.1 Producing substrate for growth bags*

Background: the substrate is the medium that the mushroom will grow on. It consists of different agricultural residues, with ideal composition depending on the individual fungi species.

Planning substrate quantity

25kg of dry substrate materials will yield very roughly 50kg of wet substrate once soaked.

Planning substrate composition

Different fungi species have individual nutritional requirements, and growth substrates need to be designed accordingly by mixing together organic materials in specific ratios to achieve a desired nitrogen level. Given below are the nitrogen concentrations (Carbon to Nitrogen (C/N) Ratios) of common substrate materials.

Given below are the nitrogen concentrations (Carbon to Nitrogen (C/N) Ratios) of common substrate materials. Mix them accordingly to obtain required nitrogen levels.

- Wood: 50-500:1 (depending on tree species)
- Corn cob: 100:1
- Rice/wheat bran: 15:1
- Cottonseed hulls: 25:1
- Sugar cane: 50:1

Given below are substrate composition for two commonly grown fungal species: Oyster and King mushroom.

**Oyster mushroom substrate**: Sawdust 63%, Corn cobs 20%, Wheat bran 15%, Calcium carbonate 1%, Calcium sulfate 1%

**King oyster mushroom substrate:** Sawdust 58%, Corn cobs 20%, Wheat bran 20%, Calcium carbonate 1%, Calcium sulfate 1%

**Water Content**

The substrate should have a final water content of 60-65% of the total substrate weight. Add water slowly to achieve this; removing excess water is difficult.

If using pre-soaked materials like corn cobs, adjust the water added accordingly.

Two tests are used to check for correct water content:

- Squeeze test: When squeezing the substrate in your hand, 2-3 drops of water should come out. Adjust water content gradually to achieve this
- Clump test: Form a clump in your fist. If it breaks apart, the substrate is too dry, and water needs to be added

Too much and too little water:

- If too much water is added, air dry the substrate or add additional dry substrate.
- Excess water can limit oxygen for the mycelium and turn the substrate blue. Insufficient water, while less harmful, will extend the growing time.

**Increasing pH**

After adding water, adjust the pH to between 7 and 8 depending on the fungus species. Some species tolerate higher pH, none tolerate lower.

Use lime (CaO) to increase the pH. Add it slowly and continuously, starting with 80% of the estimated amount. Test the pH using color test strips and adjust as needed.

Calcium oxide is preferred over calcium carbonate ($CaCO_3$). If using calcium carbonate $CaCO_3$ pH will increase during autoclaving – this is hard to get right

Add calcium sulfate ($CaSO_4$) at 1% by weight to stabilize the pH.

Stabilizing pH: once the desired pH is reached, add calcium sulfate ($CaSO_4$) at 1%by weight to stabilize the pH.

Mixing: Mix the substrate ingredients thoroughly. Use either shovels or a mixer machine.

### *4.2 Bagging and sterilizing*

Select desired bag size and start filling the bag. Compact as firmly as possible. Heavier bags have a higher yield.

Be very careful not to damage the bag by punctuating it during the compaction. This creates opportunities for future contamination.

Water accumulating at the bottom of the bag is a sign of excessive moisture in the substrate.

Add plastic neck to the bag, fix with rubber band. Close off with a matching lid.

At this stage, wait no longer than 2-3 days before sterilizing the bags to avoid contamination risks.

Place bags in the autoclave and sterilize at 121C for two hours. Ensure compliance with autoclave operating procedures

Place sterilized bags in storage shelf and let them cool down to room temperature (approximately 8 hours)

### *4.3 Inoculating the Growth Bags*

Background: in this step mushroom spawn is inserted into the grow bags within a laminar airflow to inoculate them with mycelium

Materials and tools: mushroom spawn, sterilized grow bags, large tweezer

Process:

- Two people work together for this task; the first does “clean tasks”, the second one “not clean tasks”
- Prepare the laminar airflow (LAF) and the required tools as described in previous steps. Ensure compliance with LAF operating procedures.
- Worker #1 opens the spawn bottle and uses the tweezer to break the spawn up into pieces
- Worker #2 shifts around 8 grow bags into the LAF. Ensure that they have cooled down to room temperature after autoclaving
- Worker #2 opens one bag at a time
- Worker #1 uses the tweezer to transfer around 10g of spawn into the bottle
- Worker #2 closes the lid. Once all bags are inoculated in this manner, the worker transfers them out of the LAF into transport crates.

# 5. Greenhouse management

General Conditions for Successful Mushroom Fruiting

For optimal mushroom production, ensure proper management of all four key environmental factors:

- Temperature
- Humidity
- Ventilation
- Illumination

## *5.1 Temperature control*

Greenhouse Temperature Management

- Summer greenhouse range: 22-30°C
- Winter greenhouse range: 12-21°C

**Species Temperature Categories**

Summer Strains (22-30°C):

- Yellow Oyster (*Pleurotus citrinopileatus*)
- Black Oyster (*Pleurotus ostreatus* var. *florida*)
- Pocket Oyster (*Pleurotus sajor-caju*)
- Shiitake (*Lentinula edodes*)
- Muer (*Auricularia cornea*)

Winter Strains (12-21°C):

- Enoki (*Flammulina filiformis*)
- King Oyster (*Pleurotus eryngii*)
- Chestnut Mushrooms (*Pholiota adiposa*)
- Lion's Mane (*Hericium erinaceus*)
- Black Muer (*Auricularia heimuer*)

Temperature requirements by species

| Species | Tolerated Fruiting Range | Optimal Fruiting Temperature |
|---|---|---|
| Enoki Mushrooms (*Flammulina filiformis*) | 7°C to 16°C | 13-15°C |
| Shiitake (*Lentinula edodes*) | 8°C to 30°C | 20-28°C |
| King Oyster (*Pleurotus eryngii*) | 7°C to 21°C | 13-18°C |
| Chestnut Mushrooms (*Pholiota adiposa*) | 13°C to 24°C | 15-19°C |
| Lion's Mane (*Hericium erinaceus*) | 13°C to 24°C | 18-20°C |
| Black Muer (*Auricularia heimuer*) | 12°C to 30°C | 18-26°C |
| Black Oyster (*Pleurotus ostreatus* var. *florida*) | 12°C to 32°C | 22-28°C |
| Yellow Oyster (*Pleurotus citrinopileatus*) | 13°C to 29°C | 23-25°C |
| Muer (*Auricularia cornea*) | 15°C to 33°C | 22-30°C |
| Pocket Oyster (*Pleurotus sajor-caju*) | 13°C to 29°C | 23-25°C |

### *5.2 Watering guide*

| Season | Watering Frequency | Recommended Times | Special Considerations |
|---|---|---|---|
| Winter (Lower Evaporation) | Once daily | 1:00 PM (peak temperature) | Water during hottest part of day |
| Monsoon (High Temperatures) | Twice daily | Morning and evening | Avoid watering during peak heat |
| Spring & Autumn (Variable Conditions) | Once or twice daily | First: Around noon<br>Second: Around 5:00 PM | |

**General Watering Principles:**

- Never water when temperatures exceed 30°C (promotes Trichoderma/green mold growth)
- Never let the bags dry out
- Always adjust watering frequency based on visual assessment of substrate moisture
- Watering with cold water can provide shock to induce fruiting

### *5.3 Bag management*

Proper Opening of Bags for Oxygen Supply

- Fold the plastic back to keep the opening wide and maximize air exchange
- For Enoki Mushrooms: Gradually fold the plastic neck further outward as they grow to encourage elongated stem growth

Species-Specific Bag Management

King Oyster and Pholiota (Chestnut) Mushrooms

- King Oyster: Retain around 3 mushrooms per bag
- Pholiota: Retain around 5 mushrooms per bag

**Selection process:**

- Observe mushrooms from the primordial stage and identify the strongest ones
- Remove excess mushrooms once they reach a cap diameter of 2-3 mm
- Avoid removing them when they are too small, as they are difficult to cut

**Yellow Oyster Mushrooms**

If bags develop a thick, leathery mycelium skin, this indicates temperatures are too low or kept for long time

Remediation steps:

- Remove the thick mycelium skin to allow fruiting to resume
- After removing the skin, water the newly exposed areas as with other mushroom bags
- Maintain proper temperature range (23-25°C optimal)

# 6. Mushroom cultivation on forest floor

Mushroom strain: Wine cap (*Stropharia rugosoannulata*)

### *6.1 Temperature and seasonality of Wine cap outdoors cultivation*

Temperature range

- Wine cap is tolerant of a range of a wide range of temperatures: 5-30C.
- Ideal colonization (mycelium growth) temperature is 21-24C. Ideal fruiting temperature is between 15 and 21C
- Frost is tolerated only for short periods of time

**Cropping seasons**

- Cultivation is possible year around in many climates of the HKH mid-hill region.
- Particularly well suited is plantation 1 month prior to monsoon and 1 month after the monsoon
- Timeline: on composted substrate – 1 months for composting, approx. 2 months for mycelium growth phase, approx. 2 months of fruiting phase

### *6.2 Site selection*

- Forest areas or with relatively dense canopy cover required for shading. If forest sites are not available, shade nets can be used
- Forest type: any broad-leaf or mixed forest
- Tree species to avoid: Certain types of species should be avoided in selecting sites. A small number of them present is acceptable, but they should not occur in high numbers: Conifer species such as pine and fir; the tree species that contain volatile bacteriostatic substances, such as eucalyptus and walnut
- Slope gradient should not exceed 30 degrees, to prevent planting beds getting washed away

### 6.3 *Shading Methods*

If no naturally shaded planting site is available, shading structures can we constructed. Common shading methods include the following:

- Constructing temporary shading structures: Using bamboo poles or wood logs, together with black shading nets to build a temporary shading system. However, this method requires precautions against strong winds and heavy rain, which could damage the structure
- Planting inside greenhouses: Cultivating mushrooms in soil beds within greenhouse structures
- Direct shading with black nets: Covering the cultivation area directly with black shading nets. This can be supplemented with sprinkler irrigation systems or simple manual watering using hoses.

Each method has its pros and cons. The first and second methods offer better control over environmental conditions but involve relatively higher investment costs. The third method is more cost-effective but may require frequent monitoring and maintenance to ensure optimal shading and humidity levels for mushroom growth. Choosing the most suitable method depends on the specific site conditions, budget, and scale of cultivation.

### 6.4 *Preparing compost*

The purpose of composting is to prepare a nutritious medium of such characteristics that the growth of mushroom mycelium is promoted to the practical exclusion of competitor organisms.

Materials and formulae

The compost is prepared from different agricultural residues including wheat and rice straw, sawdust, and corncobs at specific ratios. Composting materials should be chosen based on local availability and price. A list of composting formulae using different materials is given in **Annex**

**Composting procedure**

- Total time required: 25 - 28 days
- Chop/ crush materials: no pieces should be larger than 2-3cm
- Mix thoroughly and water materials until 60-65% water content. Check water content by pressing materials in a closed fist – when some drops of water can be squeezed out, the water content is correct. Too much or too little water will hinder the composting process
- Building the pile: Build a square or rectangular pile, roughly 1.5 - 2.5m high and wide; build larger piles for compost that contains substantial amounts of straw (>40%), and use at least 1.4t of dry composting material
- Turning the compost: Keep compost static for 5 days, until inside temp increases to 60C (measure with thermometer, if available); after that, turn every 3 days. Turn 6-7 times in total, no need to add more water during turning; the compost is ready when it turns brown in color and only if it doesn't have any smell of ammonia; otherwise a few more turnings are given at an interval of three days till there is no smell of ammonia.

### 6.5 *Planting bed preparation*

- Mark out planting strips of 60cm, with 60cm gaps in-between them
- Apply lime (calcium oxide) between rows for controlling contamination
- Pile up compost rows around 20cm high. Deeper beds may produce longer but take longer to fully myceliate before fruiting. Roughly 25kg of compost per meter of length
- Inoculation with spawn. Spawn amount required: 6-7% of compost substrate dry weight (between 5-

10% is the acceptable range). E.g. 60-70 kg of spawn per one ton of compost, and 500g for each 1m of compost row. Break spawn into pieces 3-5cm in diameter (smaller pieces will delay fruiting). Bury a piece 2 inch deep every 15cm in a triangle pattern across the sides and the top of the pile

- Soil cover: Cover compost with a 5cm thick covering of soil. If you can see compost shine through, soil cover is too thin
- Drainage ditches: dig 20-30cm deep drainage ditches between the rows. Take care not to expose the compost

### *6.6 Watering*

- Regularly check soil moisture: regularly check soil moisture during the complete cultivation period
- Dig down into the bed with your fingers – it should be damp, not wet
- Water accordingly – based on local climate this may mean watering every 1-2 days
- Mainly water from the ditches, but also sprinkle on top, to keep it moist

### *6.7 Fruiting and harvesting*

- Time to fruiting: approx. 2 months; throughout the season, especially after heavy rains and temperature drops
- When to harvest: Can be harvested at either button or mature stage. Button stage: harvest when caps measure 2.5 to 4 cm across. Mature stage: after they have opened their caps, but before they release their spores
- Harvest technique: Mushrooms need to be harvested by light twisting without disturbing the casing soil. Once the harvesting is complete, the gaps in the beds should be filled with soil and then watered.

Next harvest cycle: Change plot location and leave first site fallow for one cropping cycle

### *6.8 Management*

**Heavy rain**

- Check regularly – Compress soil if it gets loose, drain water if necessary
- Fill in holes in soil cover. Do not take soil out of ditch, as that is too wet - take drier soil from side

Other species that are suited for compost-based field cultivation (but not described in this document):

- *Phallus impudicus* - Common Stinkhorn
- *Coprinopsis cinerea* - Gray Shaggy Mane
- *Pleurotus flabellatus* - Pink Oyster Mushroom
- *Volvariella volvacea* - Paddy Straw Mushroom
- *Lepista sordida* - Blewit or Dirty Blewit
- *Agaricus bisporus* - Button Mushroom
- *Agaricus subrufescens* - Almond Mushroom

## ANNEX: Compost formulae

Compost Formulae Group 1 – Low straw content

Materials should be measured "dry", meaning their moisture content is below 15%

| Material | Formula 1 | Formula 2 | Formula 3 | Formula 4 |
|---|---|---|---|---|
| Broadleaf tree sawdust | 50% | 35% | 68% | |
| Broadleaf compost | 10% | | | |
| Corn cobs | 30% | | 10% | 100% |
| Corn straw | | 20% | 22% | |
| Rice straw | | 30% | | |
| Wheat/ rice bran | | 15% | | |
| Rice husk | 10% | | | |

Compost Formulae Group 2 – High straw content

All formulae that use a substantial amount of straw (>40%) require a larger compost pile, and a minimum of 1,4 ton of dry composting materials. Use same amount of spawn as you would for 1 ton of material (e.g. 50-100kg of spawn).

| Material | Formula 5 | Formula 6 | Formula 7 | Formula 8 |
|---|---|---|---|---|
| Broadleaf tree sawdust | | 40% | | |
| Corn cobs | 35% | 10% | | |
| Corn straw | 60% | | 50% | |
| Rice straw | | 40% | | 100% |
| Wheat/ rice bran | 3% | 8% | 15% | |
| Rice husk | | | 20% | |
| Cow manure | | | 12% | |
| Gypsum | 1% | 1% | | |
| Calcium oxide | 1% | 1% | | |
| Calcium sulphate | | | 2% | |
| Calcium carbonate | | | 1% | |

## 7. Conclusion

Mushroom cultivation is a highly rewarding activity that combines agricultural skill with scientific precision. However, success in mushroom farming requires **careful planning, meticulous attention to detail, and consistent management** throughout the cultivation process.

By following the steps outlined in this manual, you can successfully grow high-quality mushrooms while minimizing the risk of contamination, which is one of the most common challenges in mushroom farming. Here are some key considerations to help you get started and thrive in this venture:

1) **Start Small and Scale Gradually**:
Begin with a small-scale operation to familiarize yourself with the process, understand the lifecycle of mushrooms, and identify potential challenges. As you gain experience and confidence, you can gradually expand your operation to increase production and profitability.

2) **Choose the Right Mushroom Species**:
Select a mushroom species that suits your climate, resources, and market demand. Popular choices include oyster mushrooms, button mushrooms, shiitake, and milky mushrooms, each with specific growing requirements and market value.

3) **Create a Controlled Growing Environment**:
Mushrooms thrive in specific environmental conditions, including controlled temperature, humidity, light, and ventilation. Invest in basic infrastructure, such as a grow room or greenhouse, to maintain these conditions and protect your crop from external contaminants.

4) **Use Quality Substrate and Spawn**:
The substrate (growing medium) and spawn (mushroom seeds) are critical to successful cultivation. Use high-quality, sterilized substrates such as straw, sawdust, or agricultural waste, and ensure your spawn is sourced from a reliable supplier.

5) **Maintain Strict Hygiene Practices**:
Contamination is a major risk in mushroom farming. Maintain strict hygiene by sterilizing equipment, using clean water, and working in a sanitized environment. Regularly monitor your crop for signs of contamination, such as mold or unusual discoloration.

6) **Monitor and Adjust Growing Conditions**:
Regularly check temperature, humidity, and airflow to ensure optimal growing conditions. Make adjustments as needed to prevent stress on the mushrooms, which can affect yield and quality.

7) **Harvest at the Right Time**:
Harvest mushrooms at the correct stage of growth to ensure the best texture, flavor, and shelf life. Use proper techniques to avoid damaging the mushrooms or the growing medium, which can support additional flushes (harvest cycles).

8) **Learn from Experience and Seek Knowledge**:
Mushroom cultivation is a continuous learning process. Keep detailed records of your practices, challenges, and outcomes to refine your techniques. Attend workshops, consult experts, and connect with other growers to stay updated on best practices and innovations.

By starting small, learning from experience, and gradually expanding your operation, you can build a successful mushroom cultivation business. With dedication and careful management, you can enjoy the rewards of growing high-quality mushrooms while contributing to a sustainable and profitable agricultural practice.