# Food Forest Fungi Farm

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## Executive Summary

Western Washington University has a food insecurity problem among students, an issue that The Outback farm works to combat with donations of the produce it grows. The fresh produce from the Outback is a much appreciated addition to the offerings of the Pop Up Pantry, but there is an opportunity to expand and diversify the Outback's efforts through mushroom cultivation. Mushrooms are nutritious, becoming a popular meat-substitute, and are a key element of soil health. In the Food Forest, the Outback is striving to create a rich permaculture -- some unused space in this area would be perfect for the introduction of a mushroom cultivation area. This project will serve three purposes: to assist the Outback in its efforts to serve WWU students with provision of nutritious foods,to offer more hand-on learning opportunities for students, and to experiment with new ways to improve the soil and soil-regeneration of the Permaculture Forest.

Mushrooms are a unique element of ecosystems. Fungi can play a critical role in decomposing plant matter and balancing the nutrients in soils. Depending on the success of this project, some of the "waste" products (i.e. spent spawn and substrate) could be used as fertilizer to improve the soil and growth systems of the Outback. As the Outback experiments with mushroom cultivation and discovers what works best in their system, students will also be able to learn; It will be a great addition to Mycology classes taught on Western's campus.

Of the many local mushrooms that grow in the PNW, 6 were selected to be the best fit for the early stages of this project based on mushroom growing regions and ease of growing: Oyster, Lions Mane, Shiitake, Wine Caps, Almond Agaricus, and Chicken of the Woods. Mushroom cultivation can be complicated, and is especially hard to control in an outdoor setting, so some mushrooms will be cultivated more easily than others. Starting a 5 year plan with a broad assortment will hopefully help the Outback to discover which mushrooms will best serve all three target purposes outlined above.

This report will explore the profiles of each mushroom; what they look like, what they need to grow, how to take care of them, and how to harvest them. Also included is a step-by-step process recommendations and a budget. The Outback will be able to stay well within its means for this project and have funding left over for any unexpected or underestimated expenses.

## Introduction

Food insecurity faces many students attending Western Washington University, and providing another source of food like mushrooms can be a significant contribution to a diet. As well as the many learning opportunities available when cultivating mushrooms, the soil is improved immensely when mushrooms are present. Mushrooms will provide an additional food source, and can be used as a high-protein alternative to meat. Mushroom cultivation in The Outback will satisfy the needs of students and faculty, and improve the soil.

The aim of this project is to research and propose a plan for The Outback Farm to begin cultivating mushrooms in the future. The Outback needs a clear plan so they can begin production in the late winter of 2021. This project plan will include information about the best types of mushrooms to grow in these conditions, how to grow them best, materials needed, costs, and data for production values. In addition, there will be information on where to source mushroom spawns from, how to get funding, and a potential growth plan for the next five years.

Mushrooms grow well in wet climates, making the Pacific Northwest ideal for cultivation. The six different kinds of mushrooms recommended; Oyster, Lions Mane, Shiitake, Wine Caps, Almond Agaricus, and Chicken of the Woods, are all suitable to grow in Western Washington's rainy conditions. Initially all the mushroom spawn can be sourced locally, from either Cascadia Mushroom Company or Raintree Nursery. Spawn will only produce if given the right conditions. Commercially grown mushrooms are usually produced in bags filled with straw, layered in sawdust and wood chip beds, or inoculated in logs. Different mushrooms produce better in certain conditions, so choosing the right methods for growing each mushroom is important to maximize harvest.The mushroom production will take place at The Outback, WWU's five acre permaculture farm, in a shaded area. The area the mushroom farm will be located on has two levels, but the space may change if The Outback chooses to clear away more of the vegetation in the area.

## Methodology

### Data Collection - Preliminary research:

- Hands-on research is infeasible regarding both the pandemic and the season, so preliminary research is conducted using search engines, books and articles.
- Conducting interviews & exchanging emails is paramount in obtaining additional preliminary information. The relevant organizations interviewed were:
    - The Outback Farm
    - Cascadia Mushrooms
    - The Raintree Nursery

### Explanation of Data Collection:

- Exploring which species of fungi feasibly produce when cultivated in a specific region assist in projecting possible production rates.
- Discovering which sustainable materials are compatible with species of mushrooms that survive in the PNW region is instrumental in satisfying sustainable methods of farming
- Researching how to obtain sustainable production materials and how to successfully integrate them into operational practices will act as instructions when beginning physical mushroom cultivation.
- Determining cost & budget feasibility of production materials, labor and maintenance is essential in conducting a successful proposal.
- Gaining insight on specific cultivation inquiries, like advice concerning successful fungi growth in the specific region, can be achieved by connecting with local organizations that work closely with fungi production.
- Research was obtained to understand the occurrence of soil regeneration and the possibilities of it occurring within the intended area of cultivation. The occurrence of soil regeneration would represent a degree of success as it results in future soil feasibility and ecosystem benefit.

## Results

### Mushroom Types:

Oyster mushrooms are one of the easiest mushrooms to grow. They can grow on a variety of substrates, mature quickly, and are full of vitamins like potassium and magnesium (Sayner, 2019). Oysters can grow in raised beds or on logs and spawn can be sourced from Cascadia Mushrooms. Cascadia sells a 100 plug package for $18 and that inoculates 3-5 logs.

Wine Caps are known as the "gateway" mushroom and are also easy to grow because they are not picky about the substrate they grow on. For a prized gourmet mushroom, they are easy to identify and are not commonly mistaken for other varieties (Growing Edible Mushrooms). Wine Caps grow most widely in a wood chip bed and sawdust spawn can be sourced from Cascadia Mushrooms. Cascadia sells 4lb bags for $30 which lasts three years.

Chicken of the Woods is known for its chicken-like texture and good flavor. It is easily recognizable because of its bright yellow and orange colors and shelved appearance (Northspore). The Chicken of the Woods mushroom grows best on oak logs and the dowels can be purchased from Raintree Nursery. They sell 100 dowels for $20.99 which should inoculate 3-5 logs.

Almond Agaricus is a cousin to the White Button mushroom, and grows easily in any garden (Smallfarms). They are best commercially produced when planted in beds with big leafy plants like chard or tomatoes to retain moisture, and when given lots of compost to break down (Smallfarms). Sawdust spawn can be purchased from Field and Forest Products and they sell 5.5lb bags for $25 each.

Shiitake are one of the most popular and well-known mushroom varieties. They are known for their nutritional benefits and can be eaten in a variety of ways (Adams, 2014). They are best grown on logs, and plugs can be sourced from Cascadia Mushrooms. They sell 100 plugs for $18, which inoculates 3-5 logs.

Lion's Mane can be easily identified by its softball-like size and long spines, and is becoming more popular because of its neurotrophic capabilities (Fieldforest). When grown on logs the taste is more sweet compared to the bitter taste from sawdust, and it usually takes two years for the fruiting to begin (Fieldforest). Cascadia Mushrooms has a grow kit, but Field and Forest sells a 250 count plug spawn for $20.

### Mushroom Growing Methods:

Inoculating logs is a popular method for mushroom cultivation. Specific mushrooms may require a specific type of log to grow well, but most hardwood logs will work. Each log should be three to four feet in length and three to ten inches in diameter (Sayner, 2019). Holes should be drilled in the logs in a checkerboard pattern, then filled with spawn, and sealed with wax (Sayner, 2019). Logs should then be placed in a shady place, like under a forest canopy or against the side of a building (Sayner, 2019).

Raised beds are another method of cultivation, and are a little easier to create. Beds can also be created on a cleared out patch of ground, usually under fruit trees or other edible perennials (Growing Edible Mushrooms). The beds use a layering technique, starting with cardboard on the bottom, adding straw and wood chips, and then sawdust spawn (Sayner, 2020). This layering is repeated until the raised bed is full and then the bed must be kept moist, either by watering or rain (Sayner, 2020).

The Outback Farm has a two level area dedicated to mushroom cultivation. The lower level is approximately 11ft x 36ft and the upper level is approximately 9ft x 34ft. These measurements were taken with the area as-is, so it could change before late winter 2021. The area is shaded so there is large potential for raised beds, or ground beds in this space, as well as room for logs to be inoculated here.

## Recommendations

**Mushroom Species:** *selected based on nativity to the region, availability of spawn, and ease of growth as implied by research.*

Wine Cap, Almonds, Oysters, COTW, Shiitake & Lions Mane:

- Raintree nursery may be more expensive than the other companies listed in the budget spreadsheet, but due to its locality and the fact that they carry all 6 types of mushroom spawn needed, it is a strong contender for sourcing.
- Cascadia is less expensive and local as well, so it will be a good option if costs need to be cut, though they do not carry some of the mushroom spawn chosen for this project. Alex Winstead has said he can offer wholesale rates if needed.
- Field and Forest is not a local company, but most of their spawn is certified organic and is technically the cheapest option pound for pound/ per dowel.

Mushrooms like Chanterelle, Morel, Shaggy Mane, or King Bolete, were not selected even though they are local foragables, because it is difficult to recreate the conditions they need to grow outside of a lab environment and the sourcing of their spawn from reliable vendors is challenging.

If after year two, some mushrooms are not growing successfully, discontinue attempts to grow that type and focus on improving conditions for those growing successfully.

**One Year Plan:**

1. Sourcing (Early Winter, up to date of inoculation)
    - Start w/ a “substrate drive”; ask students to bring spent coffee grounds and spare cardboard. Order straw (no more than one bale should be needed) and ensure the wood chip piles will be stocked by inoculation season.
    - Kieth Doran is the arborist for WWU’s maintenance department - he may be helpful in sourcing logs, and getting logs that are as fresh as possible.
    - Spawn can last up to a month if it is securely refrigerated, but do not order the spawn to arrive more than a week in advance for inoculation. Freshness is important, so even though the spawn can last in a cool environment, it is in the Outback’s best interest to try and inoculated with spawn as soon as it arrives to the farm.

2. Construction (Early winter, up to date of inoculation)

- Gather logs from community sources or Outback partners. The logs should be as fresh as possible, as mushrooms feed on wood cellulose, which decays over time as logs get older.

Inoculation (Timing slightly varied, but late Winter - March - is generally good)

- Inoculating Beds
    - One will be layered with wood chips, cardboard, and Wine Cap spawn as directed in the "Results" section. The second bed (for Almond mushroom growth) will be layered in a similar fashion, but instead of only wood chips in the substrate layers it will be filled with a mixture of coffee grounds, straw, and chips
- Inoculating Logs:
    - 3-8 logs each of Oyster, Shiitake, Lions, COTW. The exact number of logs needed will depend on the size of the logs and number of dowels ordered. 100 plugs/dowels will inoculate 3-4 logs. "Number of holes = (Length of the log in cm x diameter of the log in cm) / 60" (https://grocycle.com/how-to-grow-mushrooms-on-logs-the-ultimate-guide/)
    - When the Outback is ready to start the growth phase, "shock" logs with a water bath to initiate. After this point it will be very important to maintain moisture. Setting a sprinkler in the area for 15-20 minutes a day will help, or mist each log and bed individually. They do not need to be soaking wet, but they should be a bit damp to the touch.
        - For experimentation purposes, it may be wise to shock logs in weekly sets (one of each type of log), just in case the shock causes fruiting to occur faster than anticipated.
- Prepare to combat with slugs and heavy rain:
    - Cover logs with a tarp or frost blanket after they begin to form "pins" (small white nubs emerging from holes), this will prevent rain from making the mushrooms soggy

3. Growth:

- Oyster - These mushrooms fruit in clusters with caps that are fan shaped. They have a mild odor (described in many different ways: like anise, ocean air, or just general "mushroominess"). These mushrooms can be vulnerable to beetles, but are able to "digest" any insect that tries to eat it.Fruiting should occur after warmer rains arrive. Inoculating in March should allow for fruiting in spring and possibly into summer.
- Shiitake - Shiitakes typically only have one or two mushrooms grow from each hole during fruiting. Similar to Oysters, Shiitakes inoculated in March should fruit in spring as well as autumn
- Chicken of the Woods - This is the most ambitious selection made for this project. COTW can be finicky, and may not fruit in the first year after innoculation. For the best

chance to fruit, an older Oak log will be best. This polypore has small holes on the underside rather than gills.
- Wine Cap - When mature, Wine Caps are dark & purple-ish.
- Almond Agaricus - Research indicates that Almonds are quick to fruit after inoculation, and are regarded as a summer mushroom. It would be beneficial to wait to plant them until mid Spring, as the cold weather of Winter might be too harsh for the spawn.
- Lions Mane - Lion's Mane fruits as a large clump of white “teeth”. Instead of the cap and gill shape usually associated with mushrooms, Lion’s mane is like a ball of fine needles.

4. Harvesting:
- Each bed/log should, hypothetically, fruit up to 3 times total
- Try not to disturb or destroy the bark on logs, as it keeps moisture in and that is critical to success
- To harvest from logs, twist off or cut at the base, as close to the log as possible

Oyster: Clusters should be harvested before the most mature mushrooms have fully unfurled/unrolled the edges of their fan-cap.

Shiitake: They are ripe when you can see the gills underneath and the cap is slightly curled in at the edges. Flat, uncurled caps are still edible, but technically overripe

Chicken of the Woods: Chicken of the Woods is very vibrantly colored when it is young. Over time, after fruiting, it will fade in color and become chalky. It is important to harvest this shelf mushroom before it reaches that point -- a Chicken of the Woods should be firm, but somewhat “fleshy”.

Wine Cap: Similar to Shiitake.

Almond Agaricus: When the mushrooms have developed a skirt, exposing the gills, and give off their signature almond-y scent, they are ready to harvest.

5. Propagating from mushrooms grown:
- Save a few of each mushroom that grows successfully
- Can use Agar Suspension or Spore Syringe (Carlin, 2020)
    - Agar method:
        - In a petri dish with an agar solution, put a piece of mushroom in the dish and cover. This will provide a medium for the mushroom to reproduce it’s mycelium using its spores. Make sure the piece of mushroom you are using includes the gills, where spores are stored.

        - This method makes it easy to see if mycelium is contaminated (marked by discoloration or blooms of orange or green)
        - This “lump” of mycelium can be used to inoculate substrate
    - Syringe method:
        - Take a spore print of the mushroom by placing it gills-down onto a piece of tinfoil and covering it with a bowl for 24 hours
        - Place the spore print into distilled/ sterilized water to release the spores into the liquid
        - Use a syringe to suck up the spore-infused water. You can use this syringe to inoculate substrate

**Five Year Plan - Maintenance**

Year Two:

- Repeat steps for year 1, but adjusting timing, moisture, or other elements of care based on observed needs of mushrooms
- Begin experimenting with re-inoculation in beds
- Explore possibility of inoculating garden areas with Almonds or Wine Caps for soil enrichment

Year Three:

- Repeat year 1 again, with preparations to replace failed/ spent logs or add new ones if there is enough room in the area.
    - If there is a mushroom type that is not growing successfully at this point, do not try again and focus on the mushrooms that are growing well
- Practice creating grain-spawn (and subsequently spawn dowels) by inoculating a bag of grain such as barley or rye.

Year Four & Five:

- Working to maintain what has been achieved

**Monitoring and Evaluation**

*Preliminary success:*

- Discovering feasible production materials, like logs, is instrumental in satisfying budget feasibility. Obtaining production materials within budget would represent success in moving forward with project approval.
- A proposed project approval from project sponsors would represent the opportunity to move forward and realize tangible success.

*Once physical cultivation can begin (late winter, early spring), project success can be monitored and analyzed by the following:*

- The quantity of mushrooms grown will exist as the primary rate of success. Overall production rates can be analyzed by determining the weight of mushrooms harvested, with profit being realized by determining consumption opportunity against cost of preliminary farming & operation.
- By collecting info from known consumers of the mushrooms cultivated at the Outback farm, researchers can poll satisfaction rates concerning taste, texture & culinary use.
- The occurrence of soil regeneration can be measured by taking a sample of area soil. If soil regeneration is occurring, the act of cultivating mushrooms using permaculture is successfully benefitting the ecosystem.

**Budget**
*Cap: $400-500*

For reference:

- 100 dowels inoculates 3-4 logs
- 5lbs of sawdust inoculates a wheelbarrow's worth of chips
- The Outback already has access to an electric drill

| *Item* | *Cascadia Mushrooms* | *Field & Forest* | *Raintree* | *Estimated Spending* |
|---|---|---|---|---|
| *Mushroom Spawn* | *Oysters-$18 (100 plugs)*<br><br>*Wine Caps -$30 (4lbs sawdust)*<br><br>*Chicken of the Woods- n/a*<br><br>*Almonds- n/a*<br><br>*Shiitake-$18 (100 plugs)*<br><br>*Lions mane- $30 (grow-kit)* | *Oysters-$20 (250 plugs)*<br><br>*Wine Caps- $18 (2.5 lbs sawdust)*<br><br>*Chicken of the Woods- $18 (2.5 lbs sawdust)*<br><br>*Almonds- $18 (2.5 lbs sawdust)*<br><br>*Shiitake-$20 (250 plugs)*<br><br>*Lions mane- $20 (250 plugs)* | *Oysters-$30 (100 dowels)*<br><br>*Wine Caps- $34 (5lbs sawdust)*<br><br>*Chicken of the Woods- $21 (100 dowels)*<br><br>*Almonds- $34 (5lbs sawdust)*<br><br>*Shiitake- $21 (100 dowels)*<br><br>*Lions mane- $21 (100 dowels)* | *$92-140* |

| *Item* | *Low-end cost* | *High-end cost* | *Estimated Spending* |
|---|---|---|---|
| Logs | $0 | - | $0 |
| Substrate | Straw- 13.99 (50lbs | Straw- *$17.45 | $15 |

| | | | |
|---|---|---|---|
| | from Tractor Co. in Ferndale)<br>Coffee Grounds- $0<br>Wood Chips- n/a <already an element of farm expenses><br>Cardboard- $0 | (estimate form information available form Westlyn Feed)<br>Coffee Grounds- $0<br>Wood Chips- n/a<br>Cardboard- n/a | |
| Raised beds measuring 6ft by 4ft | 2-in x 6-in x 4-ft Pine Lumber $ 6.16 each (need 16, from Lowes)<br>Nails $4.98 (1lb from Lowes) | - | $104 |
| Tarp | $5 (8ft x 6ft from REI) | $16.98 (10ft x 12ft from Lowes) | $15 |
| Propagation tools | (Spore Syringe Method)<br>Sterile Syringes $0.55 each (shroomsupply.com, need 6 minimum) | (Agar Method)<br>Prepared Agar Petri Dishes $23.20 (pack of 10, from carolina.com, shipping not calculated) | $3.30 or $23.20 |
| Beeswax/ Sealing Wax<br>*1lb is enough to seal appx 1000 dowels* | $5 @ cascadia | $6.49 @ Fungi Perfecti (1lb) | $5 |
| Funds allocated for signage (posts, paints, brushes, plaques etc) | | | $55 |

| | | | |
|---|---|---|---|
| **Total Estimate** | | | **Approx. $289 - $343** |

## Conclusion

Mushroom Cultivation at The Outback Farm will be a great addition to the permaculture farm because it can feed students during harvest season, create a space for more experiential education, and improve the soil of the permaculture food farm. The mushrooms that are recommended for The Outback to begin cultivating are Oysters, Chicken of the Wood, Lion's Mane, Almond Agraicus, Shiitake, and Wine Caps. These six kinds of mushrooms' spawn can be sourced locally from Cascadia Mushrooms and Raintree Nursery, or from Field and Forest. Materials like logs, wood chips, and wax needed for set up and maintenance will be sourced locally. Each mushroom will be most successful if grown in either raised beds with wood chips, or on logs. A recommended plan of starting to source materials in early winter will help to inoculate logs and beds by late winter or early spring of 2021. After the mushrooms grow, they must be harvested at specific times and should fruit multiple times if everything is done correctly. To refrain from buying new spawn, there are two methods of propagation: agar suspension and spore syringe. After the first year and each after, reassessments and adjustments of the elements of care, materials, and spawn will help the Fungi Farm maximize harvests. Success of mushroom cultivation at The Outback will be measured initially by mushroom growth, then through consumer feedback and soil nutrients. The Outback estimates a budget of $400-$500, and the budget shows costs for everything needed for the most success. Mushroom cultivation in The Outback Farm will provide a learning opportunity, contribute to the regeneration of soil, and help feed food insecure students at WWU.

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