

# In Vitro Growth Chamber for Imported Chestnut Tissue

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## Background

Years ago, American chestnut trees grew across the United States, but the industry was decimated when a blight was introduced in the early 1900s that wiped out the population and industry. Chestnuts were a staple dish known for their sweet, nutty flavor. Their wood was also popular in the lumber and carpentry industries because the trees grew fast, and their wood was rot-resistant. While the American chestnut industry suffered, the industries in Europe and Asia remain strong today. Currently, Nash Nurseries supplies various fruit and nut trees, flowers, shrubs, and more. They would like to grow and sell *in vitro* chestnut trees imported from Spain to revive the domestic product of chestnuts in the United States. Figure 1 outlines the differences between traditional and *in vitro* cultivation of chestnut trees.

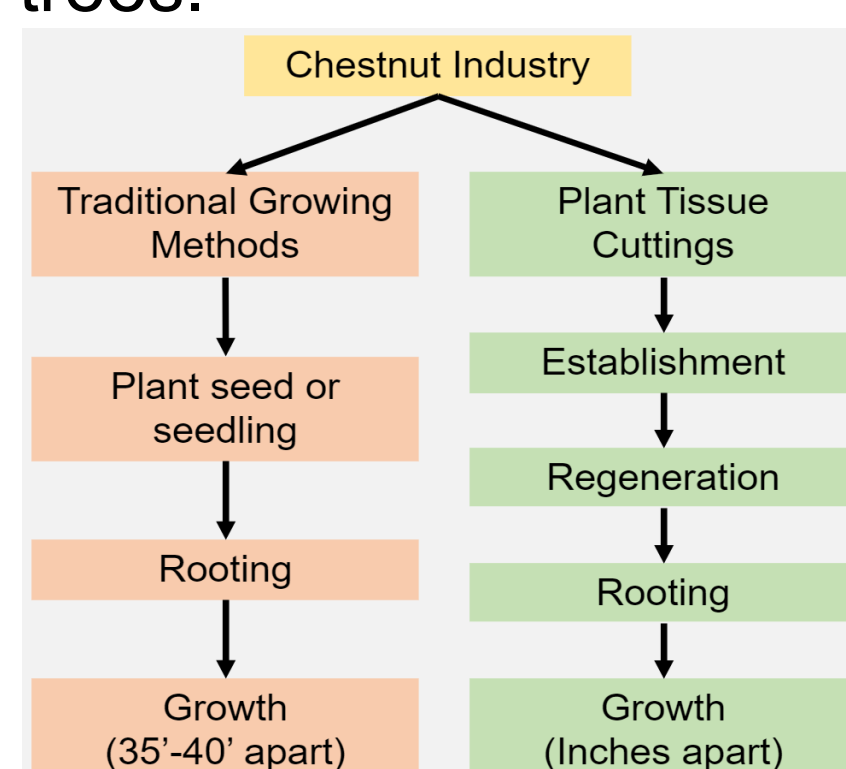


Figure 1. A flow diagram of the chestnut industry.

They have enlisted our team to design a growth chamber that supports these plants during the early stages of growth. This involves regulation of temperature, humidity, and lighting. Examples of *in vitro* chestnut tissue are shown in Figure 2.



Figure 2. Examples of in vitro chestnut tissue.

## Objectives

- Implement LED grow lights that emit 90-150  $\mu\text{mol}/\text{m}^2\text{s}$  of photosynthetic photon flux using a cool white fluorescence for 16 h/d.
- Develop an environmental control system that maintains temperature and humidity conditions:
  - Temperature of 25°C for 16 h/d while lights are on.
  - Temperature of 20°C for 8 h/d while lights are off.
  - Relative humidity of approximately 100% that can reduce to 80%.
- Supports 10,000 plants.

## Constraints

- <\$50,000 USD
- Fits within a 40' x 8' x 8'6" shipping container
- External components must not extend more than 2' from shipping container wall
- Produce guidelines that follow the USDA's SOP for the importation, growth, and quarantine of foreign plant matter.
- A plan for the growth or quarantine chamber must be submitted to the USDA that includes:
  - Physical characteristics of the facility
  - Waste generation and disposal methods
  - Pest management approach
  - Personal and general sanitation standards
  - Equipment in the system

## Design Alternatives

This system is a modular design that requires many components to insulate the environment and protect the plants from bacteria and fungi. This included selecting framing, insulation, walls, and flooring for the system. Design matrices were used to identify the best materials for this system. The selected building materials for the system were the following:

- Wood framing
- Spray foam insulation
- FRP abstract walls
- Coin vinyl flooring

The shelving units need to be designed to incorporate automated processes. The incorporation of automation into the system reduces the need for labor and entering or exiting the system, which could negatively impact the environmental conditions. Thus, reducing the need for manual interaction with the growth chamber is designed to save the clients' money in variable costs down the line. The automated processes designed for this system are as follows:

- Automated curtain
- Automated humidity
- Automated watering
- Automated light intensity control

Additional decisions include the use of Raspberry Pi to code the automated processes and to create a microenvironment within each shelving unit. The automated curtain component was later scrapped due to issues with sealing the shelving unit off from the rest of the system.

## Selected Design

To determine the amount of useable space, the framing and insulation measurements were subtracted from the interior measurements of a standard 40-foot shipping container. These calculations are shown in Figures 3 and 4, which show the measurements of the container at each level. A shelving unit and vestibule wall are also included for scale.

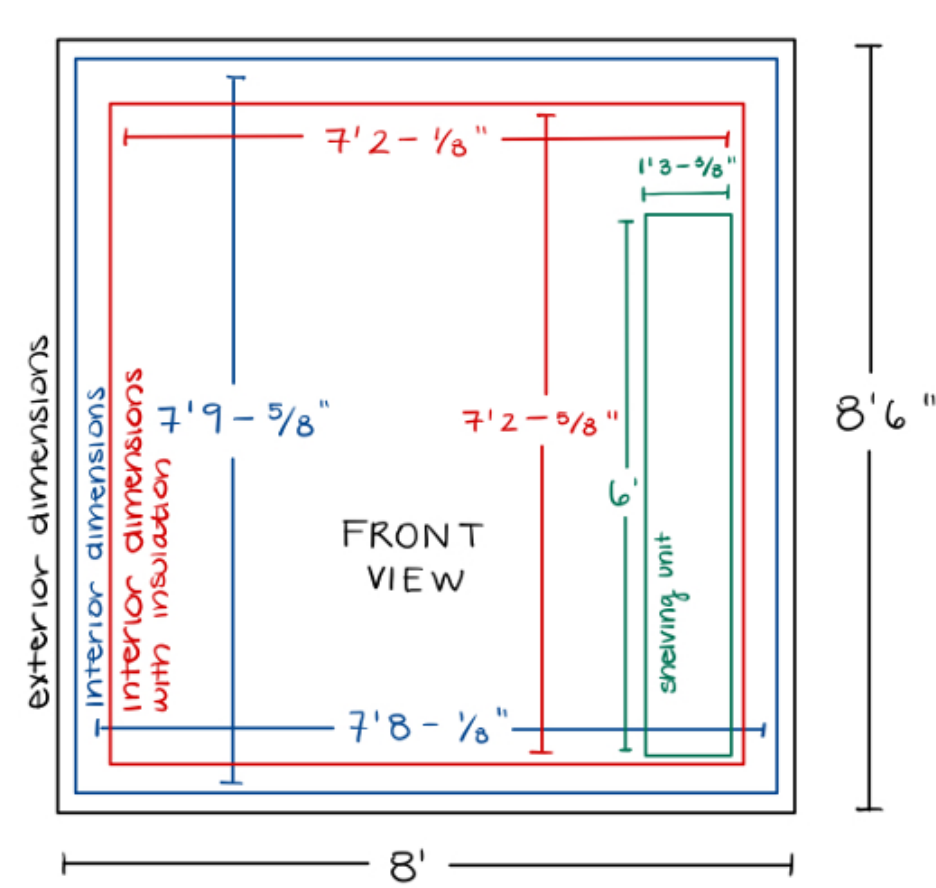


Figure 3. Front view dimensions of container.

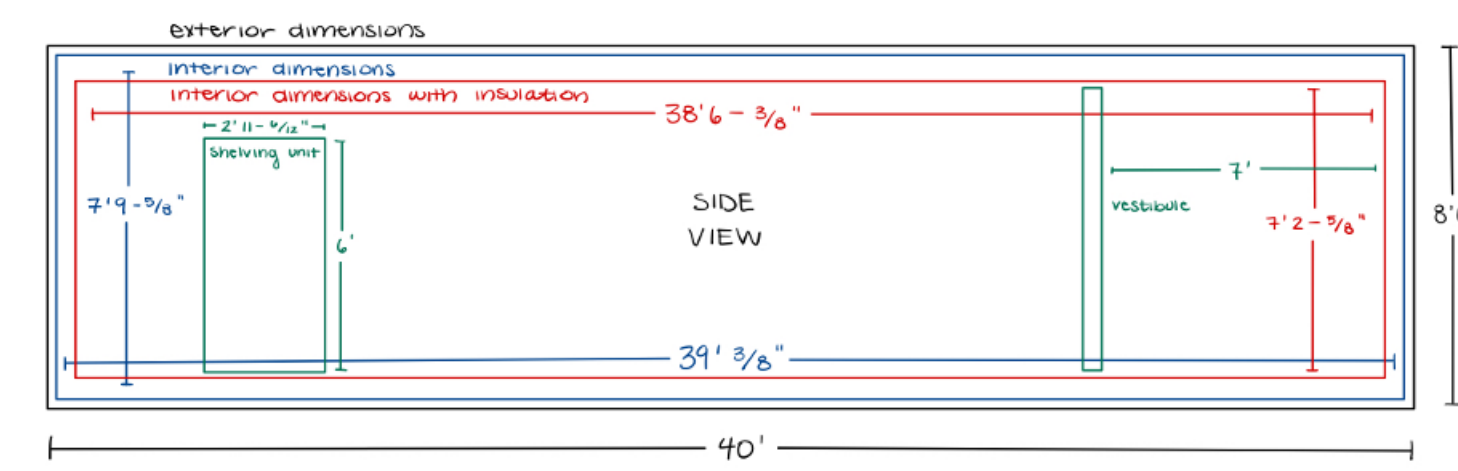


Figure 4. Side view dimensions of container.

Next, the team developed code using Raspberry Pi to implement the automated functions that control the plants' environment. These controls were designed to monitor and control the temperature, humidity, and lighting in each shelving unit. Because the needs of the plants are so specific, controlling these remotely will reduce the labor needed and helps ensure that appropriate conditions are maintained. An overview of the automated system can be seen in Figure 5.

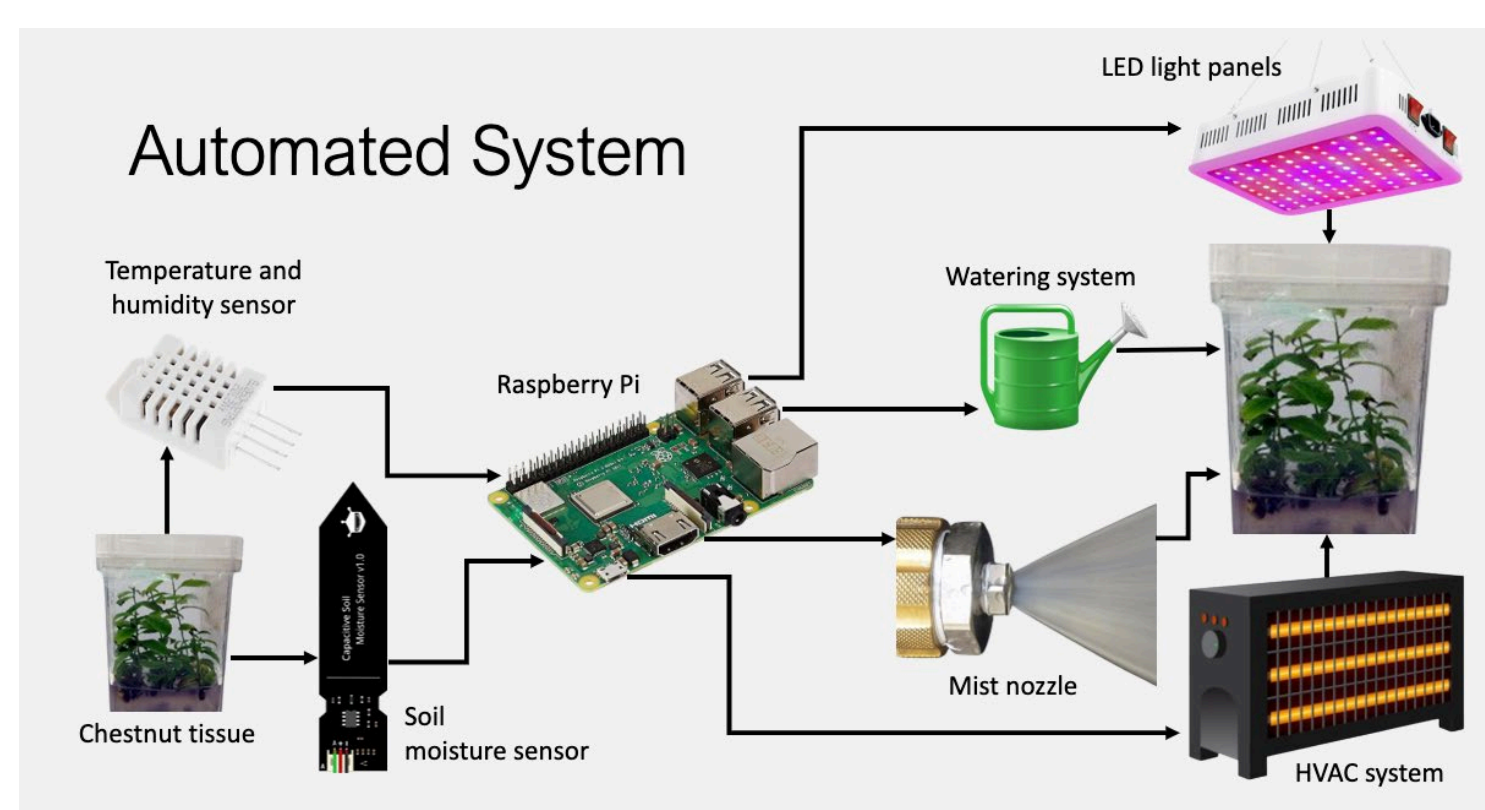


Figure 5. Automated system overview.

This image demonstrates how sensors are used to collect information from the plant, which are then transmitted to the Raspberry Pi. This is programmed to take the input of information and output some task. This means that any lighting, watering, humidifying, heating, or cooling that must take place to bring the system back to ideal conditions is then outputted by the Raspberry Pi and back to the plant.

## Selected Design, cont.

Electrical diagrams that detail the setup of these systems are also included in Figures 6, 7, and 8. These allow anyone to reproduce the system while minimizing troubleshooting.

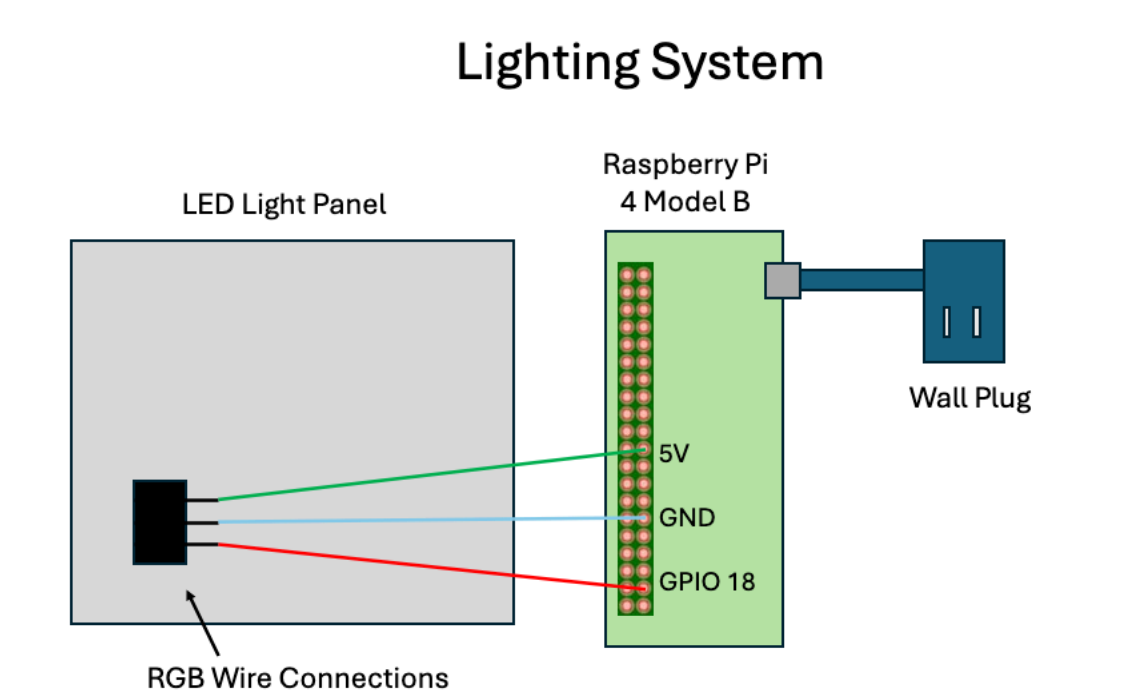


Figure 6. Electrical setup for lighting system.

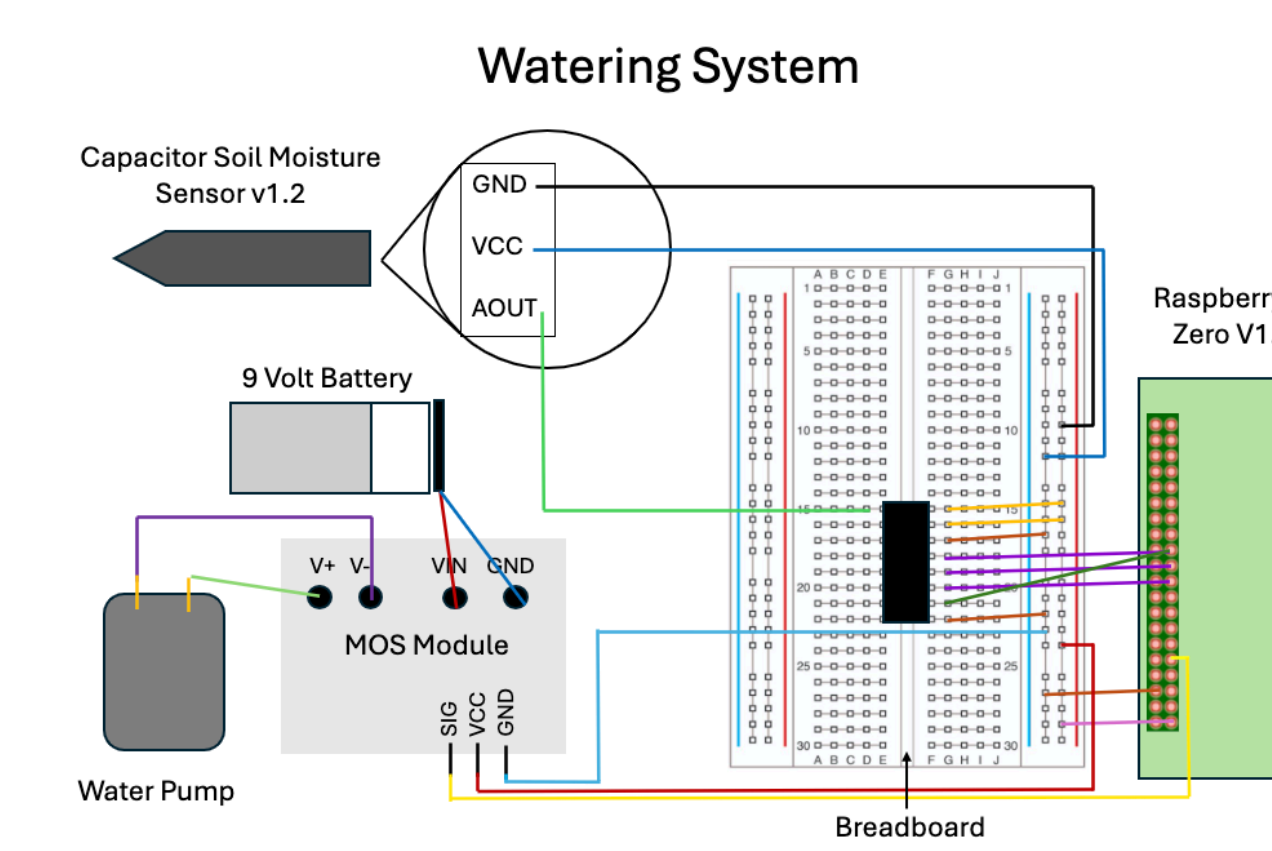


Figure 7. Electrical setup for watering system.

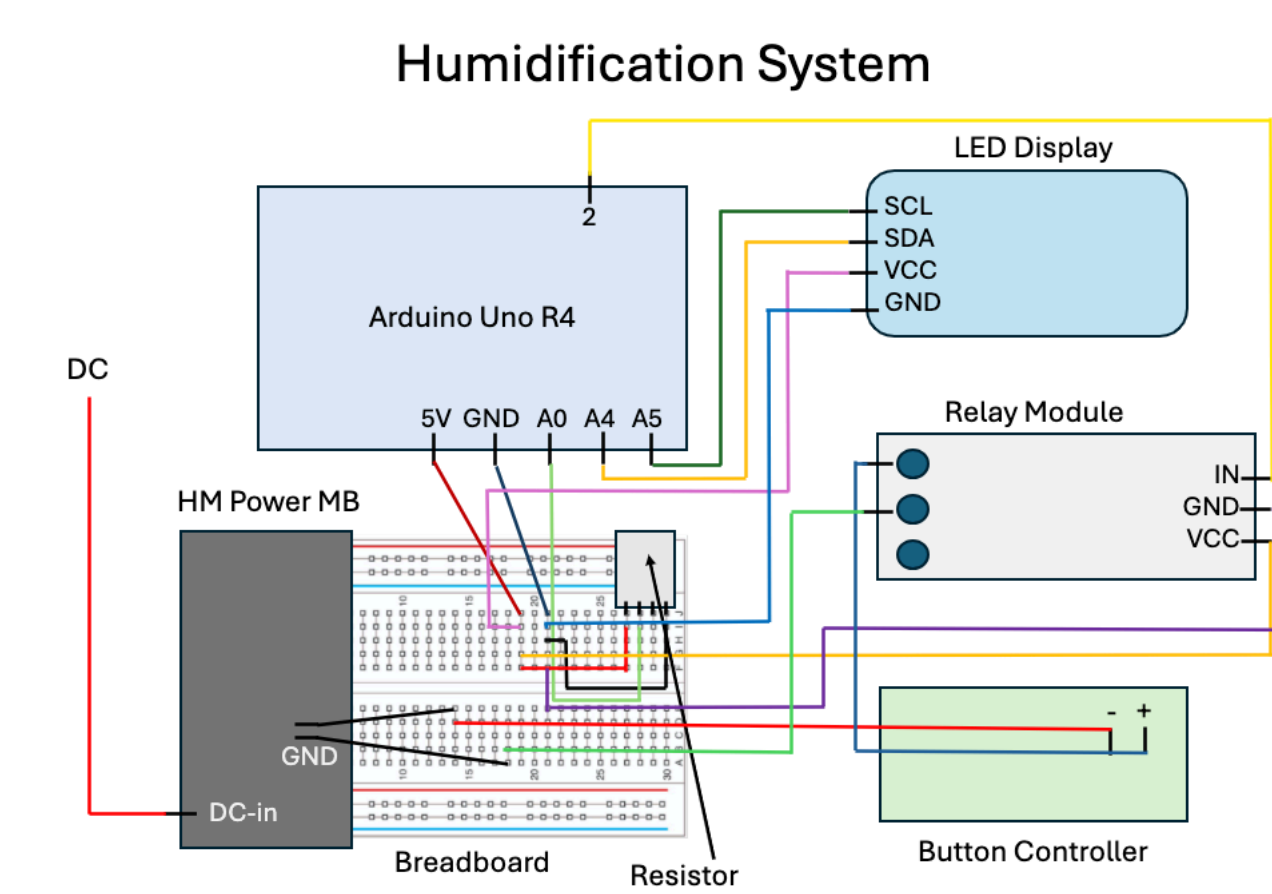


Figure 8. Electrical setup for humidification system.

To test the competency of these systems, a prototype was assembled. This prototype can be seen in Figure 9.



Figure 9. Prototype system setup.

Through this prototype, the team established the code and electrical setup. We also determined that a bakers' rack cover would work best to contain the humid environment.

## Economics

The final design of the growth chamber should not cost more than \$50,000 USD, as stated in the constraints. With an estimation that labor costs will equal 40% of the material costs, the total cost of the system would be between \$40,000 and \$42,000 USD. Figures 10 and 11 separate these costs into categories.

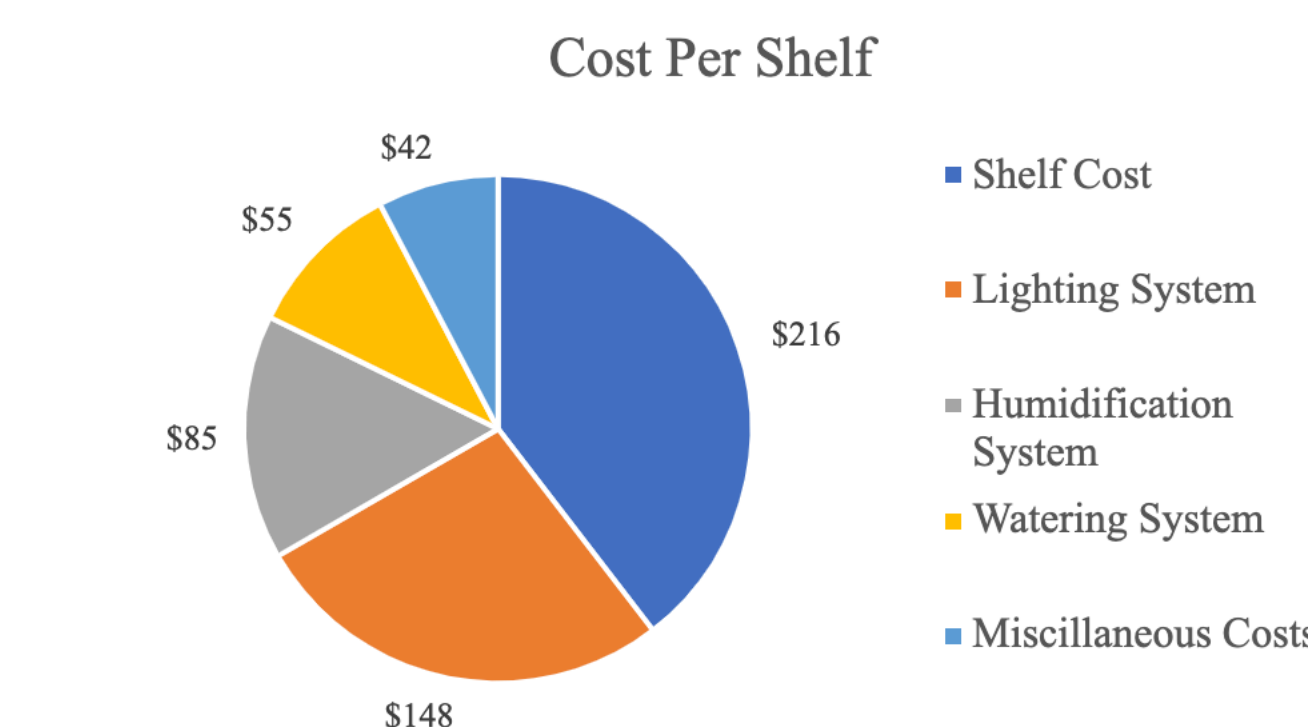


Figure 10. Cost per shelving unit by system.

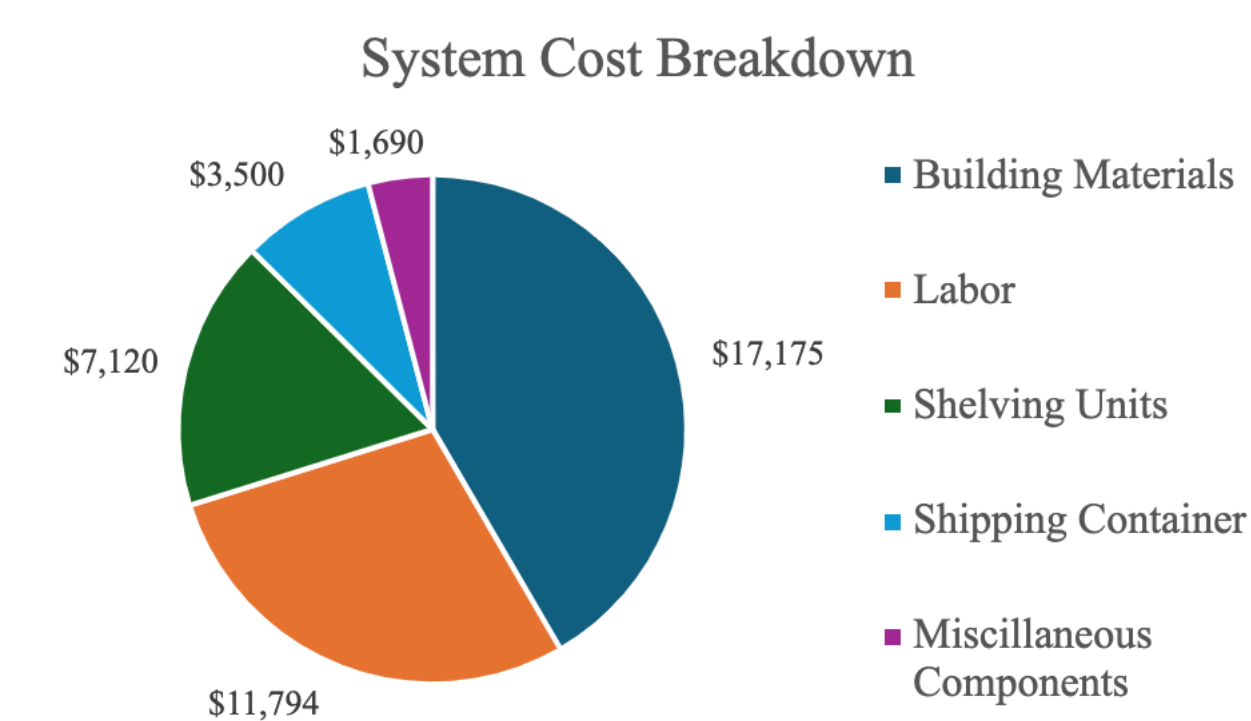


Figure 11. Cost breakdown of system.

Nash Nurseries estimates that selling enough trees to support the current level of chestnut consumption domestically would produce \$40 million in revenue. Table 1 shows the profit made for each shelving unit.

Table 1. Profit breakdown for a single shelving unit.

Component	Cost
Watering System	\$ 55.00
Lighting	\$ 148.00
Humidification	\$ 85.00
Shelf	\$ 216.00
Miscellaneous	\$ 42.00
<b>Total</b>	<b>\$ 546.00</b>
Profit Breakdown	
Plants Per Shelf	288
Cost Per Plant	\$ 2.50
Revenue Per Plant	\$ 12.00
Shelf Cost	\$ 546.00
<b>Total Profit Per Shelf</b>	<b>\$2,190.00</b>

## Select References

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