# Improving Irrigation Water Use Efficiency in High Tunnel Agriculture

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## Introduction

- Increased severity of climate related disasters is a major issue for people around the globe, but especially for those in the agricultural industry.
- Atmospheric $CO_2$ levels have risen over the years, and so have global average surface temperatures (Lindsey & Dahlman, 2023) and, as a result, the variability in climatic conditions has increased in frequency and severity (Li et al., 2021; Climate Change Is Causing Global Hunger, n.d.).
- Increased severity, variability, and frequency of disasters will affect crop yields, and this is predicted to lead to more frequent and greater economic downturns (De Winne & Peersman, 2021).

### Food Needs:

- Better food resource management is needed (World Health Organization, 2019)
- The world's population will continue to grow, and with that food needs will grow (United Nations, n.d).
- Climate change related disasters are becoming more common (*Climate Change Is Causing Global Hunger*, n.d.), and this makes growing food more difficult.

### High Tunnels:

- High tunnels are unheated structures where a plastic covering is placed over a steel or plastic structure (Gu, 2021).
- They provide protection against harmful climatic conditions made worse by climate change and increased $CO_2$ levels, such as torrential rain (Gu, 2021; Rich, 2023). They also provide protection against UV radiation (Gu, 2021; Rich, 2023). High tunnels further provide protection against cold and frost, extending the growing season (Gu, 2021; Brown, 2006).
- Plants are usually irrigated using drip irrigation, small sprinklers, or hand watering (Majumdar, 2018).
- Water for these irrigation systems comes from water sources besides rain, for example, aquifers.
- Irrigation cannot come from rain because of the impermeability of the plastic coverings.
- Water runs off of the plastic coverings and is wasted.

## Methodology

**Test**

common materials for least amount of water loss

**Test Uncommonly Used Materials**

Nature used as inspiration for choosing materials.

Materials tested for least amount of water loss

**Develop proposal for high tunnel usage**

Proposal suggests possible way for material to be used on a high tunnel

**Figure 11.** Position of the manifold in relation to the scaled high tunnel.

**Figure 12.** Water container, in which 6 L of water was placed and distributed.

## Problem Statement

High tunnel water usage is inefficient because of rainwater waste, and the dependence on other, usually underground, water sources.

## Engineering Objective

The aim of this project is to develop a method for collecting rainwater from high tunnels.

## Specific Procedure

- Different high tunnel cover materials were tested.
- Materials similar to commercially used covers.
- Materials similar to natural phenomena.

Firstly, 5 materials representing commercially used covers were tested.

- 500 mL of water were dropped from a height of 67.5 in
- a 14 by 13 by 2 inch plastic container was used to collect water.

Next, 3 materials considered to have characteristics similar to those seen in nature, like the moss in figure 15, were tested and were compared against the best performing material from the previous test.

- 6.05 L of water were dropped onto each of the materials 5 separate times from a height of 65 inches.

The half-thickness PVC loofah mat was tested in the same way.

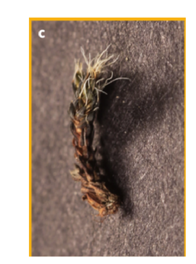

**Figure 15. S. caninervis Adapted from Pan, Z. et al. (2016). The upside-down water collection system of Syntrichia caninervis. Nature Plants, 2(7), 1–5. https://doi.org/10.1038/nplants.2016.76**

**Figure 5. Normal positioning of the pressure valve switch.**

**Figure 6. 3 mm polyethylene.**

**Figure 7. Clear Plastic Mat with Conical Spikes**

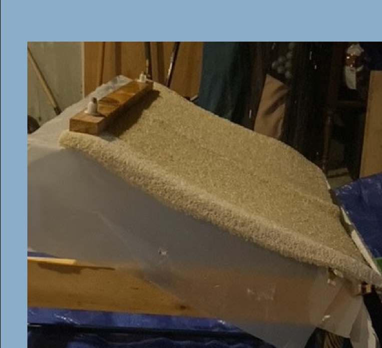

**Figure 8. PVC Loofah Mat.**

**Figure 9. Clear Plastic Mat with Grass-like Protrusions.**

**Figure 10. Half-Thickness PVC Loofah Mat.**

**Figure 13. Close-up of Normal PVC Loofah Mat.**

**Figure 14. Close-up of Half-Thickness PVC Loofah Mat.**

## Results

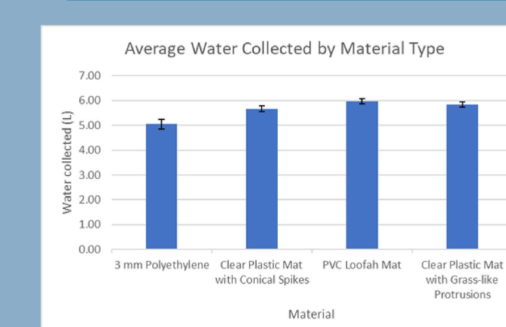


**Figure 1. Graph of average water collected for each of the materials inspired by nature**

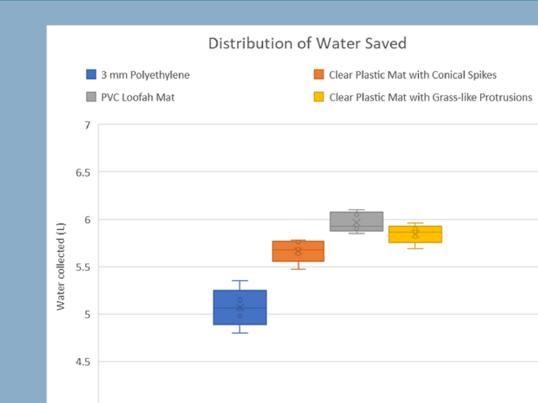


**Figure 2. Box and Whisker Plot showing the distribution of water collected per material.**

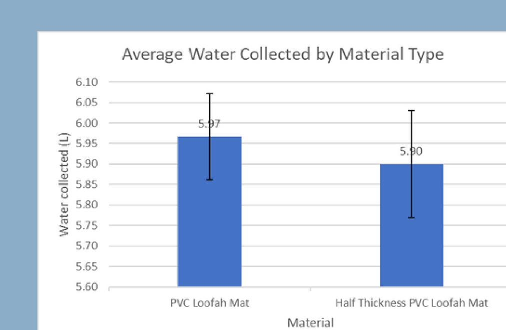


**Figure 3. Bar graph showing the comparison of amount of water collected for both thicknesses of the PVC loofah mat.**

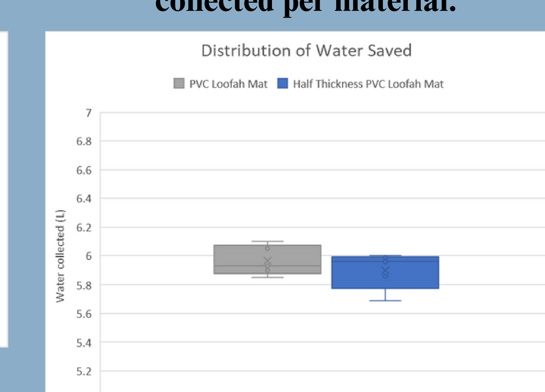


**Figure 4. Box and Whisker Plot showing the distribution of water collected per thickness of PVC loofah mat.**

## Analysis

Materials inspired by nature:

- The PVC Loofah Mat had the highest average amount of water collected.
- 3 mm Polyethylene performed the worst.
- The 3 mm Polyethylene had the biggest distribution in the data.
- The median of the PVC loofah mat box plot was located closer to the lower half. This may indicate the presence of an outlier.

Half-Thickness PVC Loofah Material:

- A Mann-Whitney U test returned a U value of 10, which was greater than the Critical U value for the two sample sizes.
- The box sizes for the two thickness of PVC loofah mat are similar. The shift downwards could indicate that thickness is important.

## Conclusions

Materials Inspired by Nature:

- Having an uneven texture may contribute to less water loss.
- Outward protrusions on the material may have allowed water that splashed to reencounter the material and be collected.
- The structure of the PVC loofah mat may have reduced the impact of the water droplets, making it perform better.
- The PVC loofah mat collected more water than was put into the system during run 4.
  - Every test was primed with water beforehand; however, it is possible there was extra water left within the material.

Comparison between different thickness PVC loofah mats:

- The distribution of the half-thickness PVC loofah mat may have been lower because there was less material to reduce the impact felt by the water droplets. This indicates impact reduction is important.

## Proposal

As a result of the data collection, I propose a concept for a material that would reduce water lost to high tunnels.

- This material would be made out of PVC plastic, and have a similar structure and texture to the PVC loofah mat tested here; however, it would be transparent or semi-transparent.
- It would be the same or similar thickness to the half-thickness PVC loofah mat.
- The material would be laid on top of the normal high tunnel cover.
- Gutters would be attached to the sides of the high tunnel, leading to storage containers.

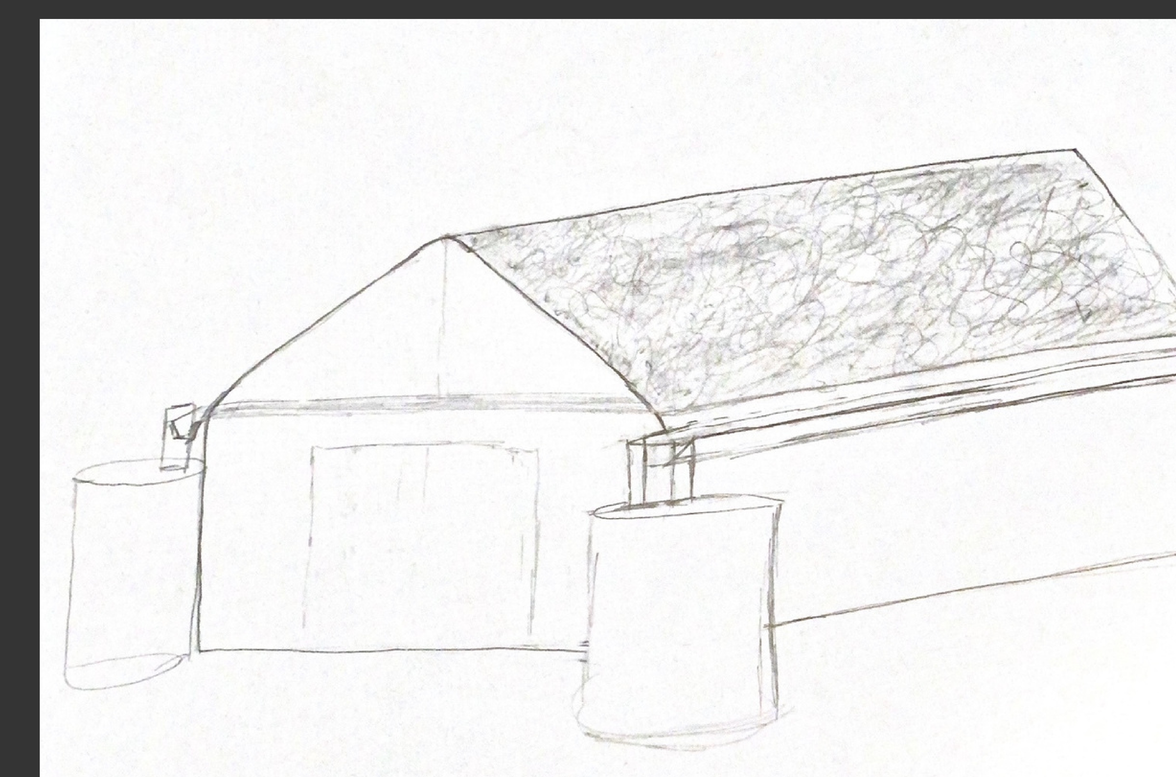

**Figure 16. Drawing of high tunnel with proposed cover and water collection technique.**

## Future Work

- Water can get stuck within the PVC loofah mat, and contribute to some water loss. In the future, similar sponge-like materials could be tested to determine a better way to reduce the amount of water trapped in the mat.
- The material was not tested on a quonset, or curved style high tunnel. Rerunning the experiments on this type of tunnel may yield different results.
- Could look at how the water is stored and how it is distributed and could possibly optimize these.

## Criteria for Materials

- The material must reduce the amount of water lost compared to the control.
- The material must be similar to phenomena in nature.
- The material must be able to be placed on the scaled high tunnel structure and be clamped down.
- The material must be available to buy.

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