

Optimization of Alginate Hydrogel Bead Formulations for Enhanced Rehydration and Structural Stability in Soil

Emily Hwang, Asad Bin Zaman, Ryan Hansen, PhD, Tim Taylor Department of Chemical Engineering, Kansas State University, Manhattan KS, 66506

Background

Agricultural soils with high sand content typically have low water-holding capacity, causing water to drain quickly beyond the root region. This causes increased dependence on freshwater resources to maintain agricultural productivity. Improving soil water retention is therefore an important challenge for sustainable agriculture.

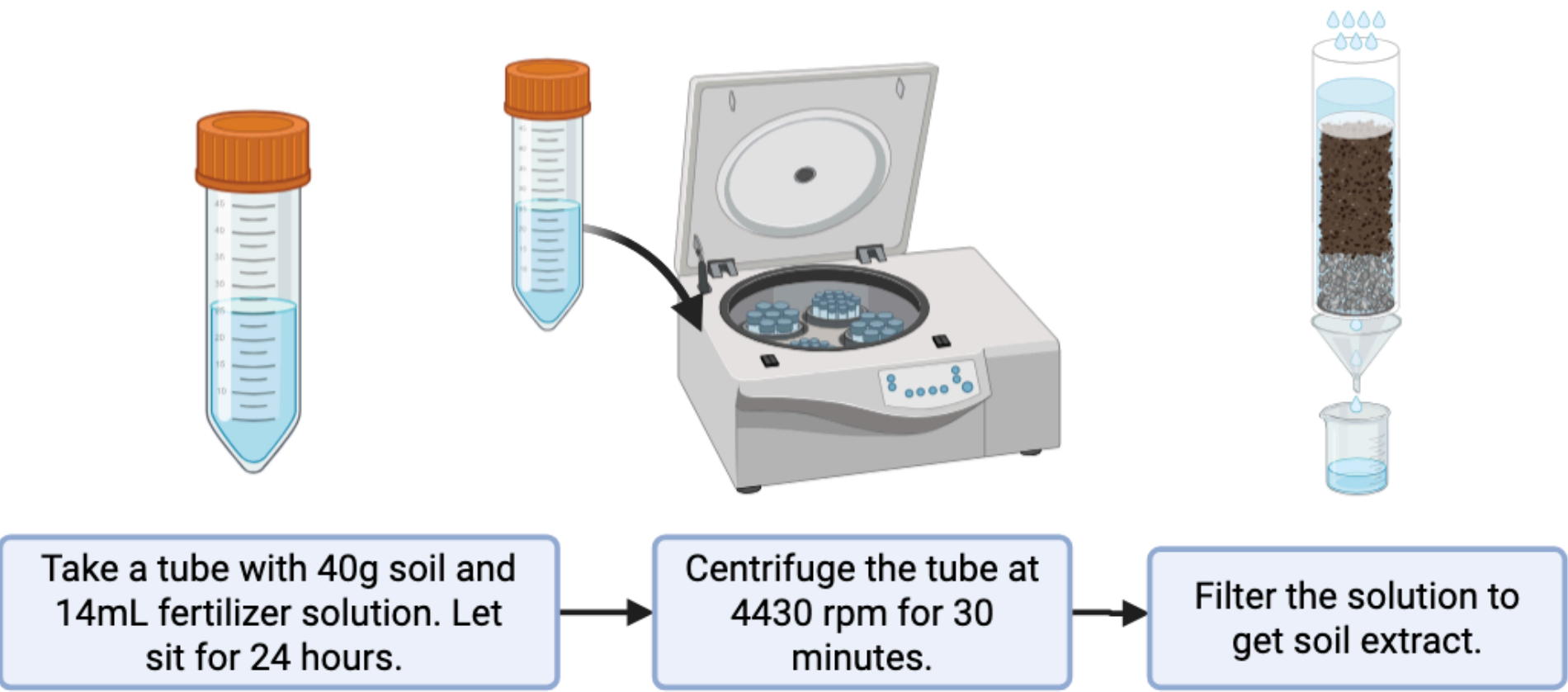
This project investigates alginate-based hydrogel beads as a strategy to improve soil water retention and support the future delivery of beneficial bacteria to plant roots. By optimizing hydrogel formulation and crosslinking conditions, the project aims to develop beads that increase plant water availability and support sustainable agricultural water management.

Objectives

- Optimize hydrogel formulations to improve rehydration
- Investigate the effect of hydrogel formulations on maximum water holding capacity in soils.

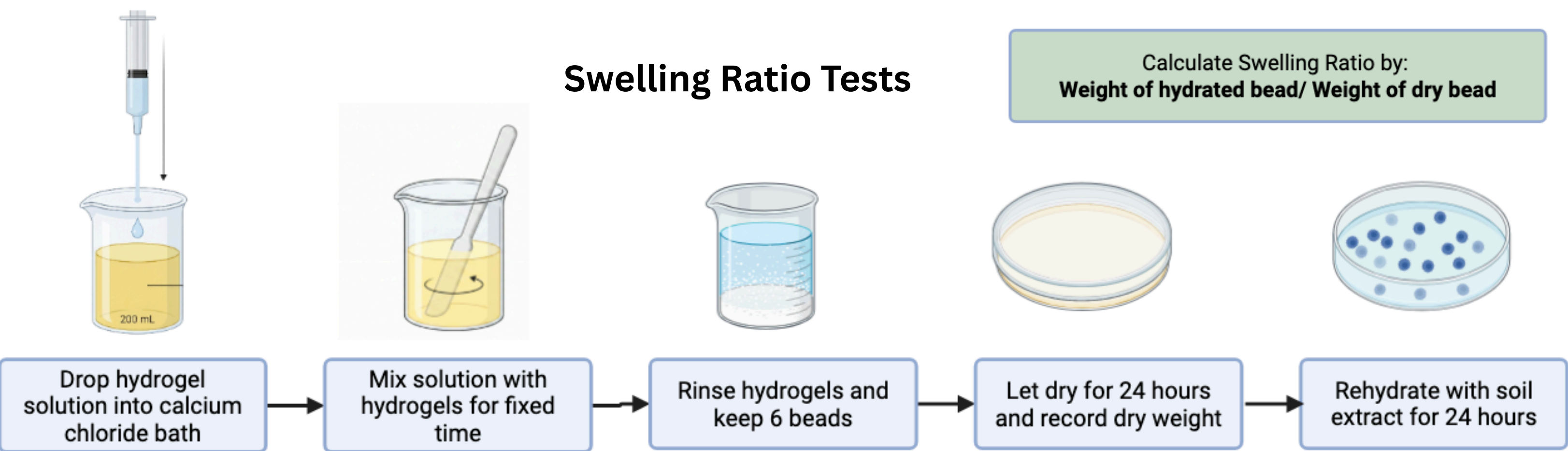
Methods

Soil Extract Collection

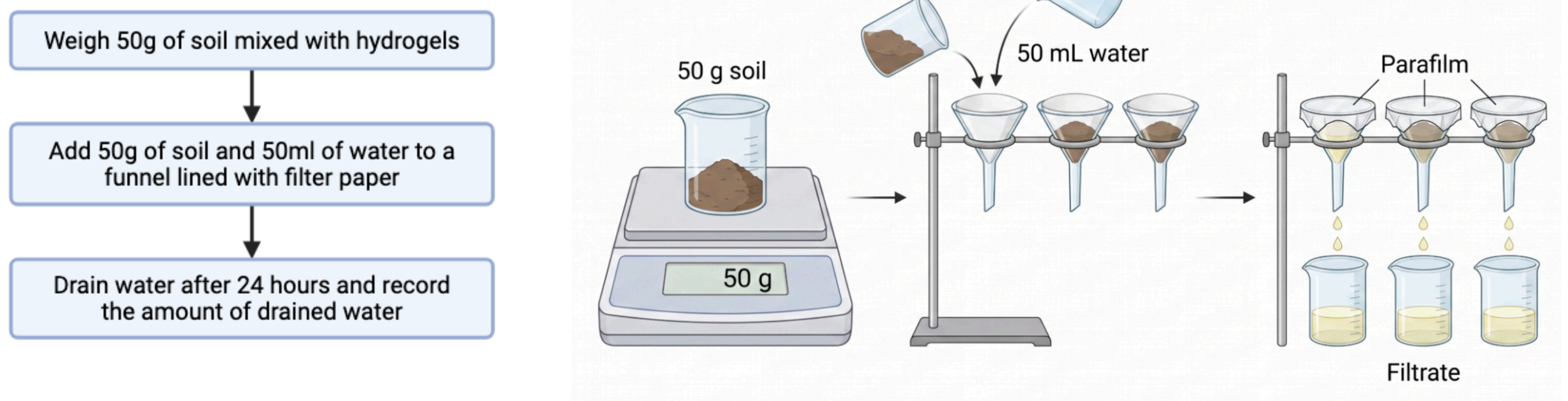


Swelling Ratio Tests

Calculate Swelling Ratio by:
Weight of hydrated bead / Weight of dry bead

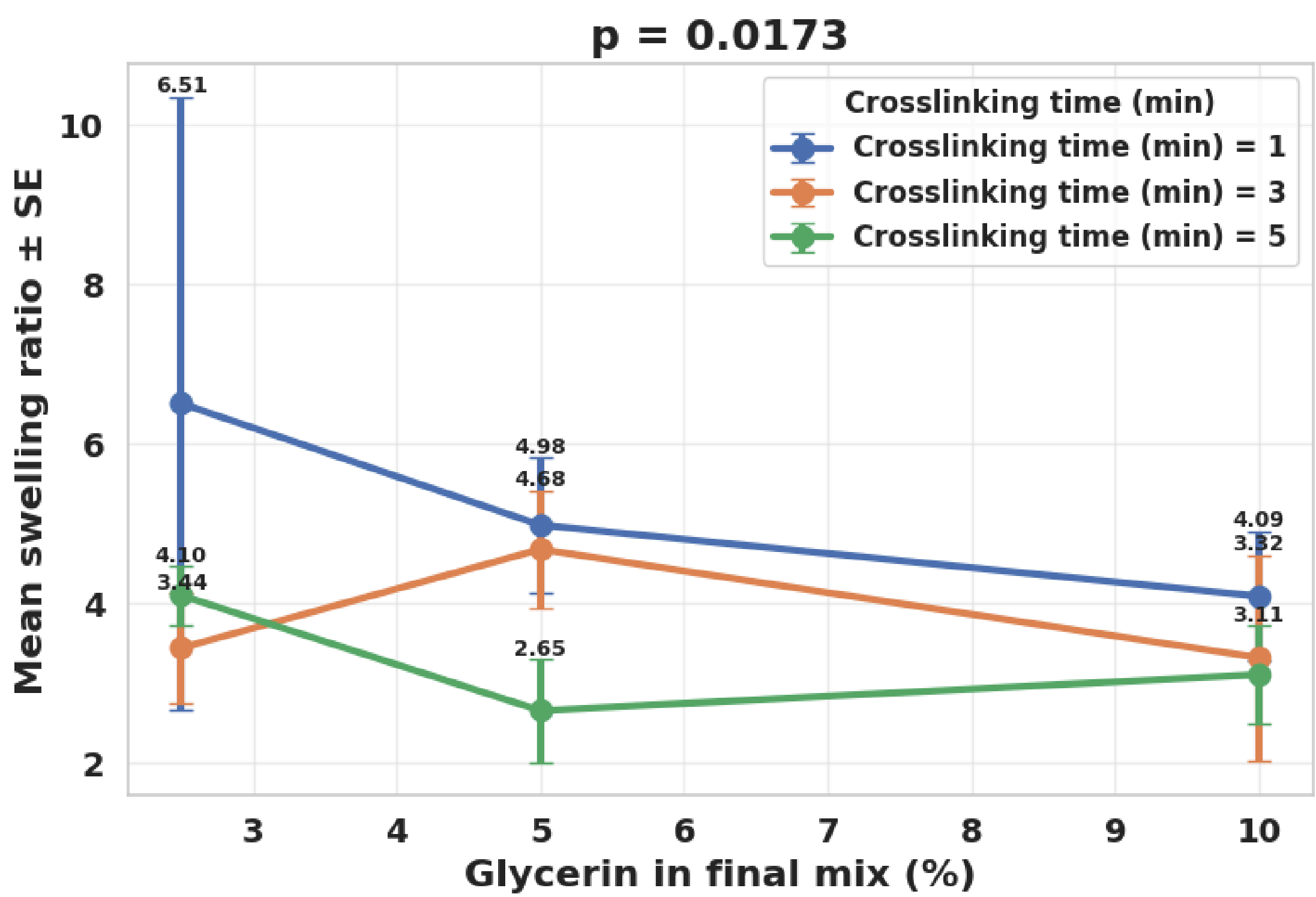


MWHC



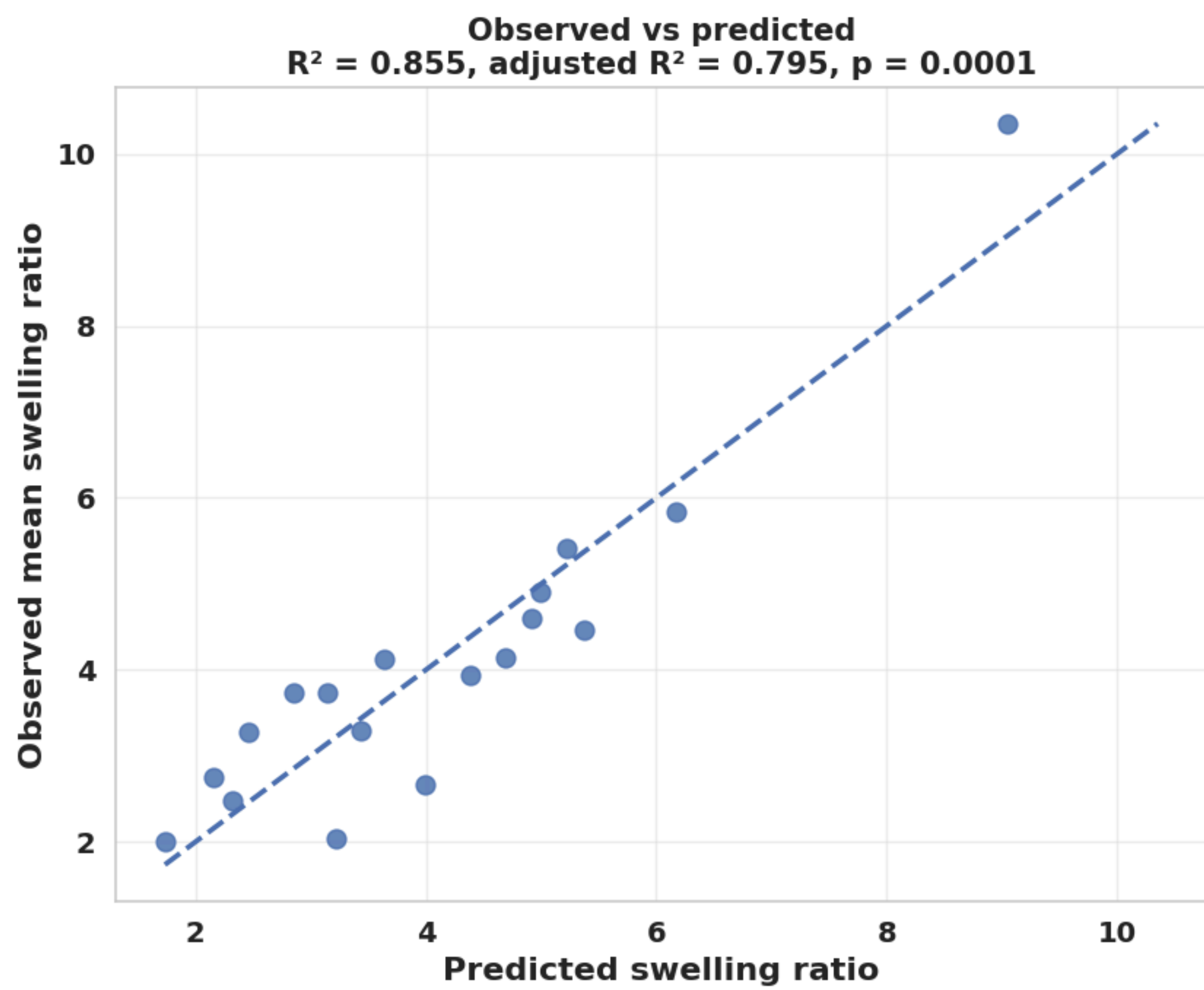
Results and Discussion

Figure 1. Interaction between glycerin concentration and crosslinking time on hydrogel swelling ratio.



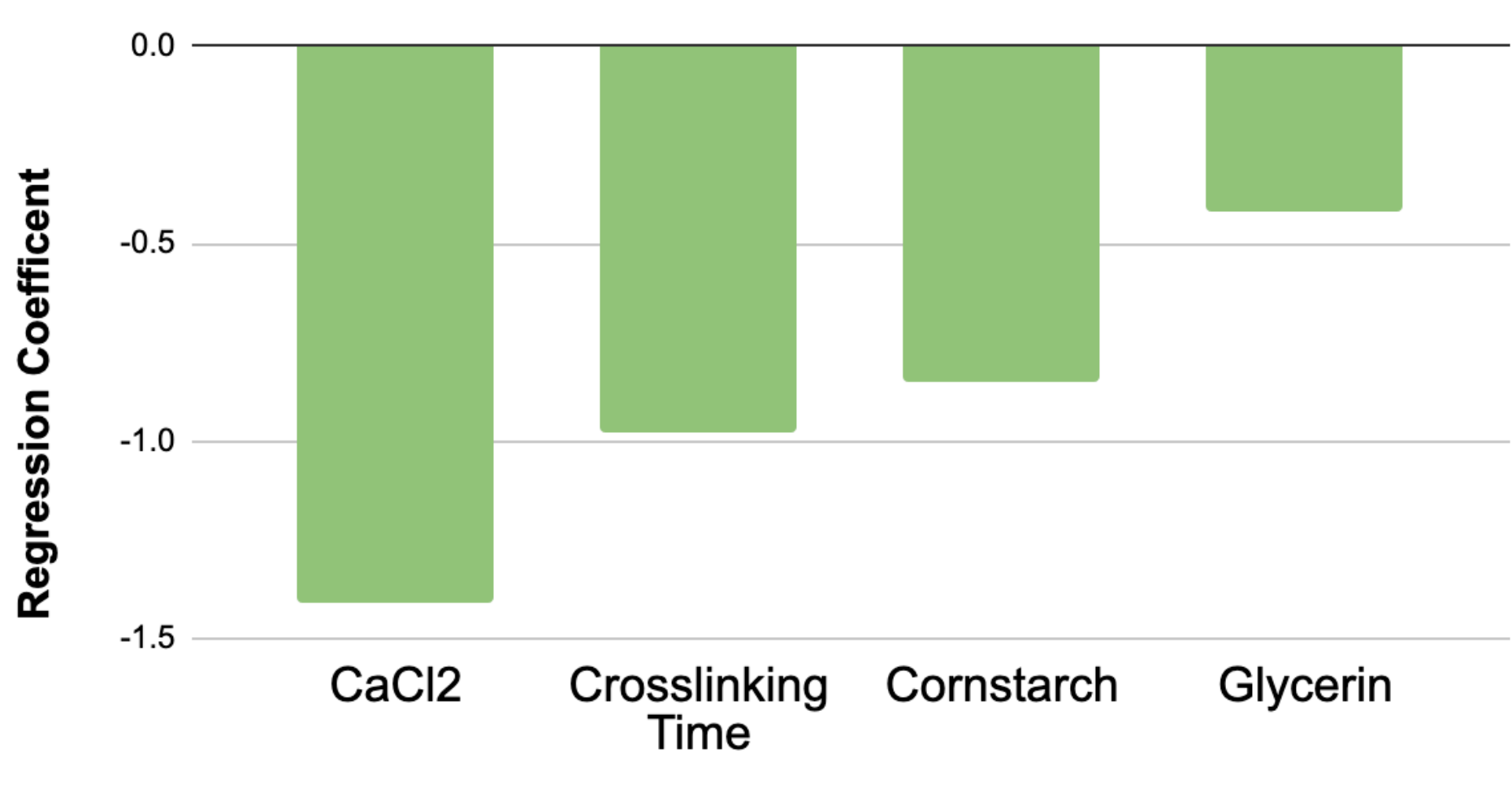
Longer crosslinking times reduced swelling, but increasing glycerin partially offset this effect.

Figure 2. Regression Model Predicting Hydrogel Swelling Ratio

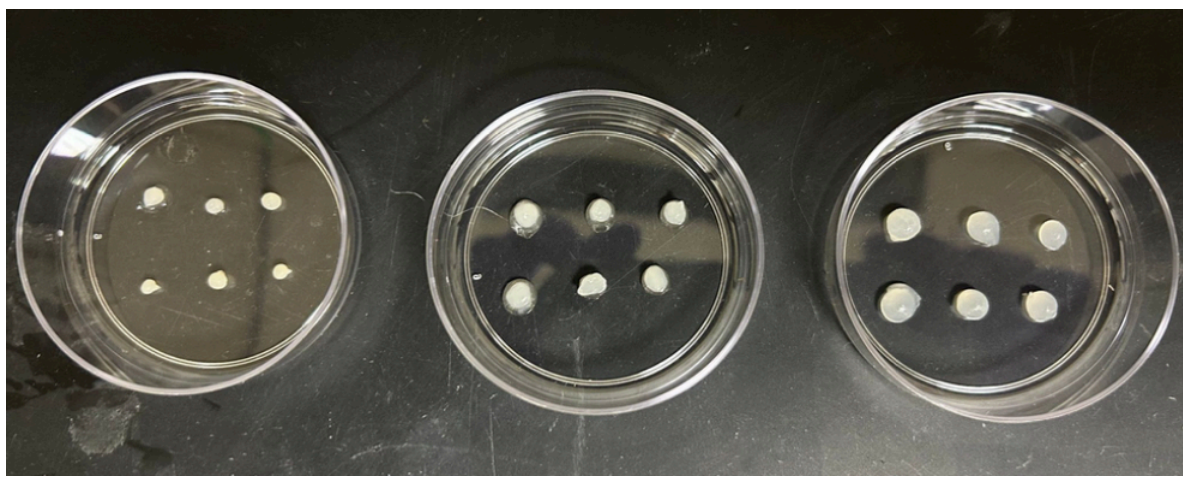


The regression model accurately predicted swelling ratio ($R^2 = 0.855$).

Figure 3. Relative effect of formulation variables on hydrogel swelling ratio based on regression coefficients.

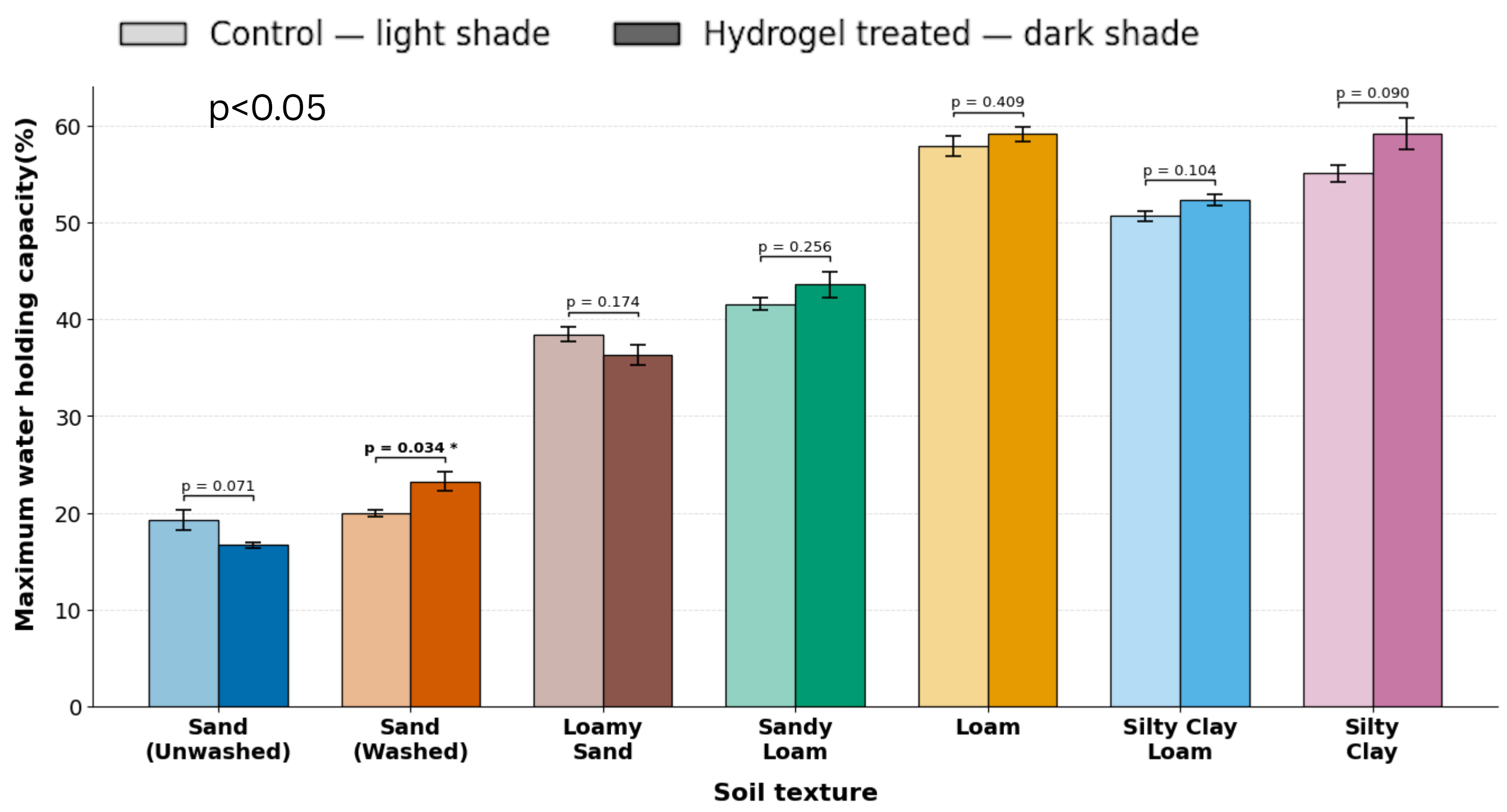


Calcium chloride exhibited the largest negative effect on swelling, followed by crosslinking time, cornstarch and glycerin.



Representative hydrogel bead formulations exhibiting low, medium, and high swelling ratios.

Figure 4. Effect of Alginate Hydrogels on Maximum Water Holding Capacity(MWHC) of Different Soil Textures



Alginate hydrogels significantly increase water storage in washed sand, but dissolve and lose effectiveness in alkaline (unwashed) sand.

Conclusion

- **Formulation:** Calcium Chloride had the greatest influence on hydrogel swelling. Glycerin partially offset the reduction in swelling caused by longer crosslinking times.
- **Application:** These formulations show strong potential for improving water retention in specific sandy soils, but soil pH must be managed to prevent hydrogel degradation.
- **Future Work:** Next steps will evaluate bacteria-loaded bead delivery and test stability under varied field-scale soil pH levels.

Acknowledgements

This work is supported by the NIFA Research and Extension Experiences for Undergraduates (REEU) Program grant no. 2024-68018-42431/project accession no. 1032359 from the U.S. Department of Agriculture, National Institute of Food and Agriculture. This research was also supported by the National Science Foundation (Award #2316295)



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