Can Biodegradable Hydrogels Help Conserve Water In Farming?

Project Report 2024 - Akshita Rawat

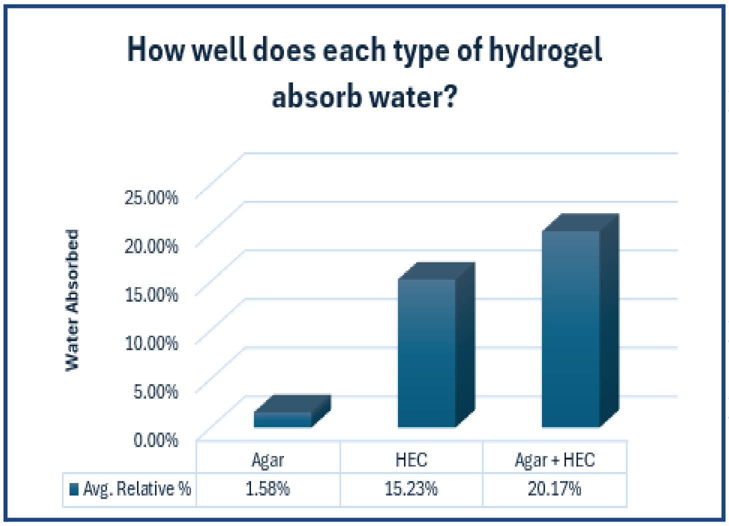
Introduction : In recent decades, the escalating challenges of water scarcity and unsustainable water usage in agriculture have initiated the exploration of innovative solutions. Among these, hydrogels have emerged as crucial components in agriculture, showcasing remarkable water-absorption and retention properties, even under high temperatures. As hydrophilic polymers, they have an immense impact on soil regeneration and restoration, impacting various soil characteristics such as permeability, density, structure, and evaporation rate. Superabsorbent water and other liquid polymer hydrogels have the potential to significantly influence soil texture and infiltration rate, thereby playing a pivotal role in addressing concerns surrounding water scarcity in agricultural settings. However, their degradation typically occurring within 2-5 years under exposure to fertilizer salts, raises environmental and health-related concerns. Notably, the breakdown of hydrogels can yield acrylamide, a potent neurotoxin and potential carcinogen, posing risks through skin contact or airborne exposure.

Addressing these challenges, my project endeavors to introduce biodegradable hydrogels meticulously designed to tackle water scarcity across industries while simultaneously enhancing soil moisture retention and reducing water consumption in agriculture. This initiative is driven by the urgent need to combat climate change and unsustainable water practices, aiming to foster environmental sustainability and promote innovative solutions to critical environmental challenges. Drawing inspiration from the severe droughts witnessed in British Columbia, Canada, the project seeks to make a positive impact on climate change by developing biodegradable hydrogel solutions that benefit the agricultural sector and contribute to broader efforts in conserving water resources and reducing carbon footprints associated with water-intensive farming practices. Through these concerted efforts, the project aspires to promote a greener and more sustainable future while addressing pressing concerns associated with hydrogel degradation and the production of harmful byproducts like acrylamide.

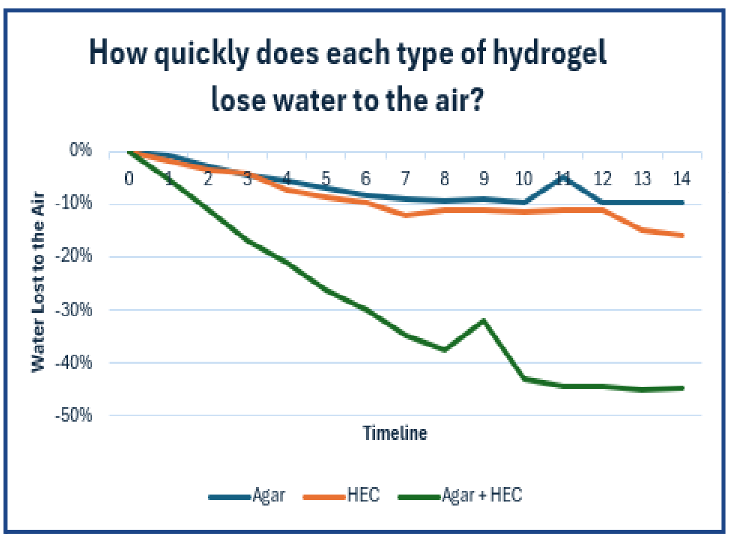
Experiment Procedure :

In conducting the experiments, the procedure unfolded in a systematic manner across three distinct parts. Initially, hydrogels were synthesized using agar, hydroxyethyl cellulose (HEC), or a combination of both, labeled as Hydrogel #1, Hydrogel #2, and Hydrogel #3 respectively. Following this, the hydrogel samples were subjected to two sets of tests. Firstly, their water absorption and desiccation behavior were evaluated over a 14-day period, commencing from February 8 and concluding on February 22, with regular measurements taken to gauge absorption rates and response to drying conditions. Secondly, the moisture retention capabilities of the hydrogels were assessed in soil, both with and without their incorporation, over the same timeframe. Pots were prepared with soil, monitoring the moisture levels to discern any discrepancies between the groups. Throughout the process, meticulous attention was paid to labeling, documentation, and adherence to safety protocols to ensure the integrity and reliability of the experimental outcomes.

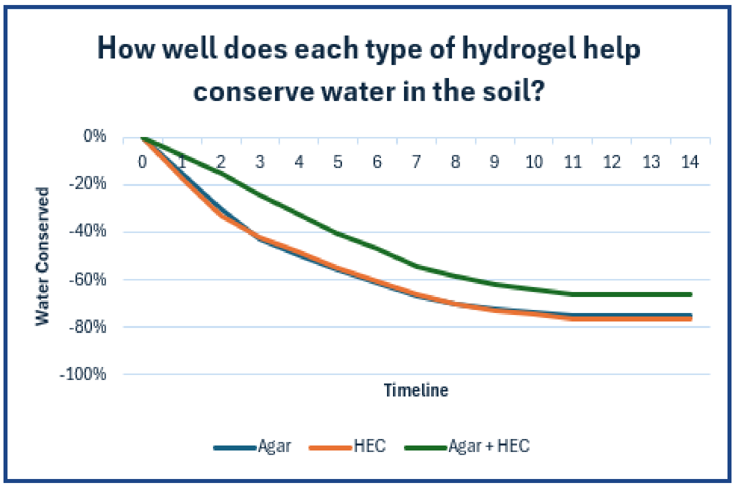
Results :



The bar graph, conducted over a 14-day period from February 8th to February 22nd, compares the water absorption capacities of the three hydrogel prototypes, revealing significant performance differences. Notably, the agar combined with hydroxyethyl cellulose (HEC) composite stands out with the highest absorption rate, averaging 20.17%. In contrast, the agar hydrogel displays the lowest absorption capacity at just 1.58%, while the HEC hydrogel falls in between at 15.23%. These variations in water absorption may be attributed to differences in the physical and chemical properties of the hydrogel components, such as porosity, crosslinking density, and affinity for water molecules.



This line graph, conducted over the same 14-day period from February 8th to February 22nd, examines the rate at which each type of hydrogel loses water to the air, with measurements presented in negative percentages to signify water loss. This graph features the average of each day of each hydrogel. Among the hydrogel prototypes tested, the agar combined with hydroxyethyl cellulose (HEC) hydrogel exhibited the highest rate of water loss, with an average percentage of -44.67% on the final day. Conversely, the agar hydrogel displayed the least water loss, with an average percentage of -9.59% on the last day. The HEC hydrogel fell between the two, with an average percentage of -15.75% on the final day. These findings suggest that the composition of hydrogel materials significantly influences their susceptibility to water loss, with the agar + HEC composite demonstrating greater vulnerability to dehydration compared to the other prototypes.



The third line graph, which includes the average of each day of each hydrogel, evaluates different hydrogel types' efficacy in conserving water in soil, uncovering significant performance discrepancies. Hydroxyethyl cellulose (HEC) hydrogel emerges as the most effective, boasting the highest average percentage of water conservation at -76.77%. The agar hydrogel falls in the middle with an average of -74.94%, while agar combined with HEC demonstrates the lowest water conservation capacity at -66.08%. Notably, the control pots scored an average of -73.74% on their last day, conserving less water compared to the highest scoring hydrogel. These results, coupled with insights from previous graphs, suggest that while the agar + HEC composite may initially absorb water more efficiently, its higher water loss rates diminish its overall effectiveness in water conservation. Additionally, it's worth noting that the average results mentioned are of the last day of the experiment, providing a snapshot of the hydrogels' performance at the conclusion of the study. The negative percentages indicate that the pots of soil are desiccating over time.

Conclusions : During a 14-day evaluation of three hydrogel prototypes, significant performance differences were noted in water absorption, evaporation susceptibility, and soil moisture retention. The composite agar+HEC hydrogel consistently absorbed the most water, averaging 20.17%, surpassing agar and HEC individually. However, it also exhibited the highest vulnerability to water loss, with an average of -44.67% on the final day. Agar had the lowest absorption rate at 1.58% but demonstrated the least water loss at -9.59% on the last day. HEC showed balanced performance in absorption and evaporation. Regarding soil moisture retention, HEC proved most effective, conserving an average of -76.77% of water, surpassing agar and agar+HEC composite. Agar+HEC, despite high absorption, exhibited lower water conservation at -66.08%. Overall, while the agar+HEC composite excels in absorption, its susceptibility to evaporation compromises its effectiveness in water conservation. Therefore, HEC emerges as the most promising option for agricultural water conservation due to its balanced performance.

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