NMHS
National Mission on Himalayan Studies

Standard Operating Procedure (SOP)
Development of biodegradable superabsorbent Hydrogels for agriculture application

NMHS Project: Development of biodegradable superabsorbent hydrogels for agriculture application to contribute water conservation in agricultural fields.

PI: Dr. Sachin Bhaladhare Tripura University (A Central University) Suryamani Nagar, Bikramnagar Agartala, Tripura

Climate change and increasing demands for food and water have significantly affected the volume and quality of food globally. Agricultural food production largely depends on the quality of the soil and the supply of adequate water.The mismanagement of soil by human activities, such as soil pollution, and deforestation, results in soil erosion and reduced fertile land, limiting food production. Most importantly, insufficient rainfall and inefficient use of available water significantly affect food production and quality. The proper management of accessible water using promising technologies is imperative to overcome the existing limitations and to improve quality and volume for global demands. The technologies and materials need to be developed that can efficaciously absorb water and water-soluble fertilizers and release them expeditiously in a sustained and controlled manner. Hydrogels as superabsorbents are considered potential materials due to their appealing properties, such as the high absorption capacity of water and water-soluble substances, i.e., fertilizers, into their network. Subsequently, the absorbed water and fertilizers can be released to arid and semi-arid agricultural land to furnish enough moisture and nutrients for plant growth. This practical water management exercise can conserve water to improve the water-retaining capacity of agricultural soil.

In the current study, we prepared CNFs-reinforced cellulose hydrogel nanocomposites based on hydrophilic cellulose derivatives, carboxymethyl cellulose sodium salt (NaCMC), and hydroxyethyl cellulose (HEC), for agriculture applications. The prepared hydrogel nanocomposite will act as a water reservoir by absorbing and holding the water in the network and releasing it to the plants in a controlled manner resulting in reduced irrigation efficiency and improved plant growth. The natural crosslinker citric acid (CA), found in citrus fruits, was used to crosslink polymer chains to form a hydrogel network. CNFs were extracted from cotton fibers using acid (H_2SO_4) hydrolysis.

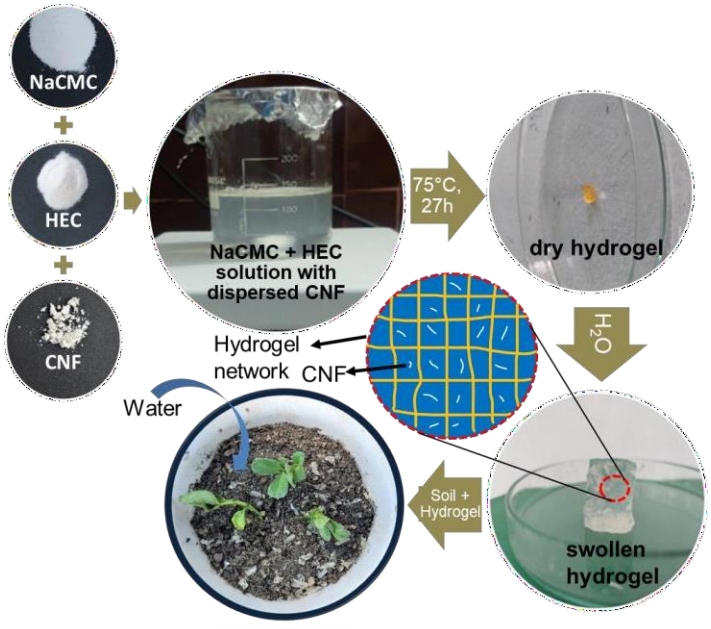


Figure 1: Synthesis of hydrogel and application for plant growth

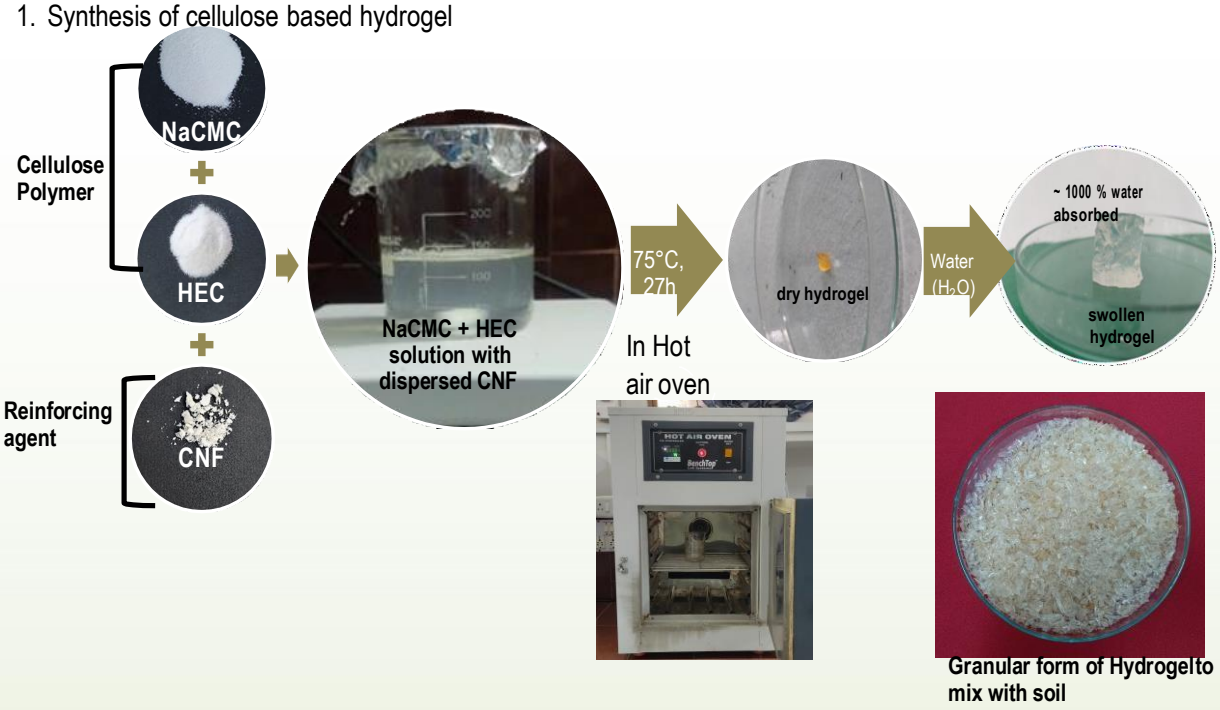
Step 1: Collection of raw materials/chemicals

NaCMC (average Mw-90,000 Da), HEC, and sulfuric acid (H_2SO_4) (99%) were purchased from SigmaAldrich Pvt. Ltd., USA. A crosslinker citric acid (CA) (anhydrous) was purchased from SRL Laboratories Pvt Ltd., India. Sodium hypochlorite (NaOCl) (4%) and sodium hydroxide (NaOH) (97% extra pure) were purchased from Thermo-Fisher Scientific India Pvt. Ltd. and LobaChemie Pvt. Ltd, Mumbai, respectively. Potassium hydroxide (KOH) pellets were obtained from Avarice industries, India. Cotton fibers were obtained locally to extract CNFs. All the chemicals were laboratory grades and used as received. Synthesis reactions were carried out in deionized water (DI).

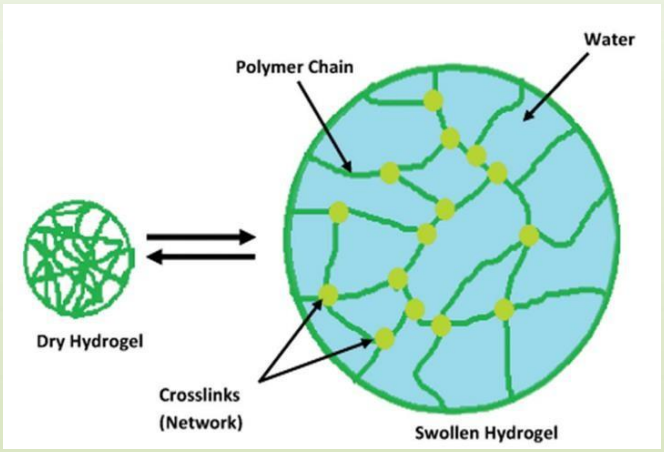
Step 2: Synthesis/manufacturing of cellulose based hydrogel based on NaCMC/HEC and citric acid crosslinker.

The hydrogels were prepared using different ratios of NaCMC/HEC, i.e., 2:1 and 3:1, with varying concentrations of CA crosslinker (10%, 12%, 14%, and 16%). To prepare a hydrogel, an appropriate weight of NaCMC was initially dissolved in 100 ml of distilled water (DI) in a 250 ml glass beaker with continuous stirring. After that, HEC was slowly added to the solution and stirred until it completely dissolved. Then the required concentration of CA crosslinker was added to the clear cellulose solution and dissolved thoroughly. The solution was kept in a hot-air oven at 45°C for 24 h to evaporate the water partially. Then the temperature increased to 75°C for carrying out the hydrogel synthesis reaction and allowed the reaction to take place for 27 h. The prepared hydrogel was washed entirely in methanol and DI water to remove unreacted monomers and dried for further experiments. To prepare a CNFs-reinforcedhydrogel nanocomposite, the required number of CNFs was added into the NaCMC/HEC solution with continuous stirring. Then the reaction was carried out as described above. The 2:1 ratio of NaCMC/HEC and 10% of CA with varying percentages of CNFs were used to prepare hydrogel nanocomposites.

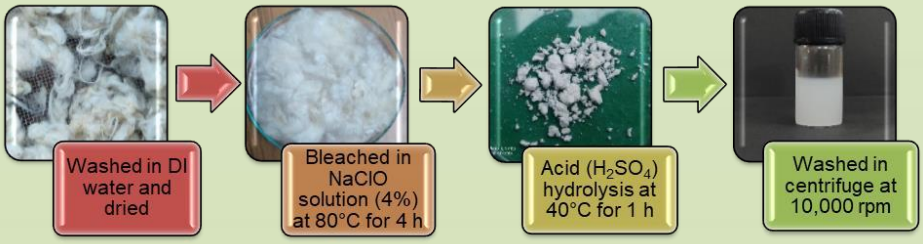
1. Synthesis of cellulose based hydrogel



2. Structure of dry and swollen hydrogel (representation)

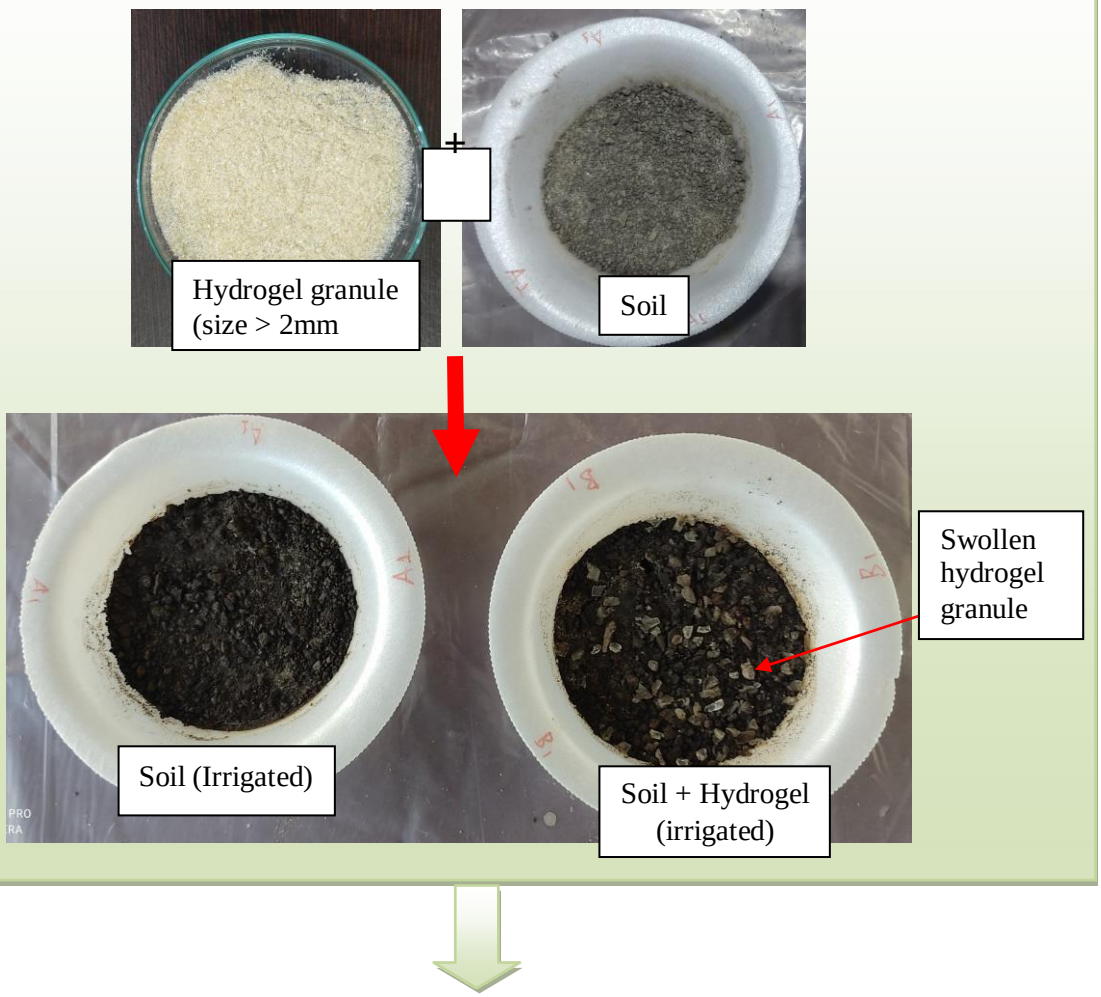


3. Extraction/synthesis of crystalline CNFs from cotton fibers through acid (H_2SO_4) hydrolysis



Step 3: Mixing of hydrogel (2%) with black clay soil

Prepared hydrogel was grounded into the granular form (size: > 2 mm) and mixed with black clay soil available in Tripura state.
2% (wt %) of hydrogel (based on total soil weight) used to prepared hydrogel modified soil. Hydrogel modified soil was watered (irrigated) for plant germination. One reference pot with only soil was also irrigated for comparison.

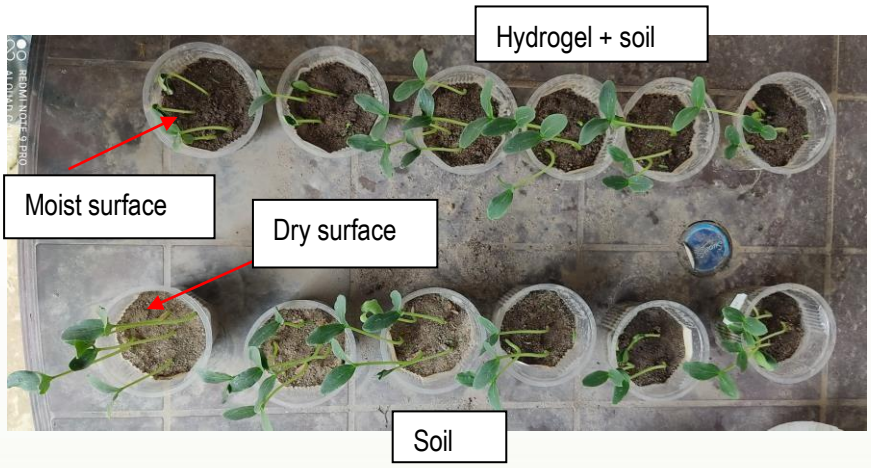


Step 4: Plantation of seeds (cucumber) into pots of hydrogel modified soil and only soil

Cucumber seeds were planted in hydrogel modified soil and unmodified soil and observed the plant growth for 30 days. Pots were watered (irrigated) in appropriate intervals (every 48 hrs.) Observed the plant growth and available water to the plants.

4th Day Growth

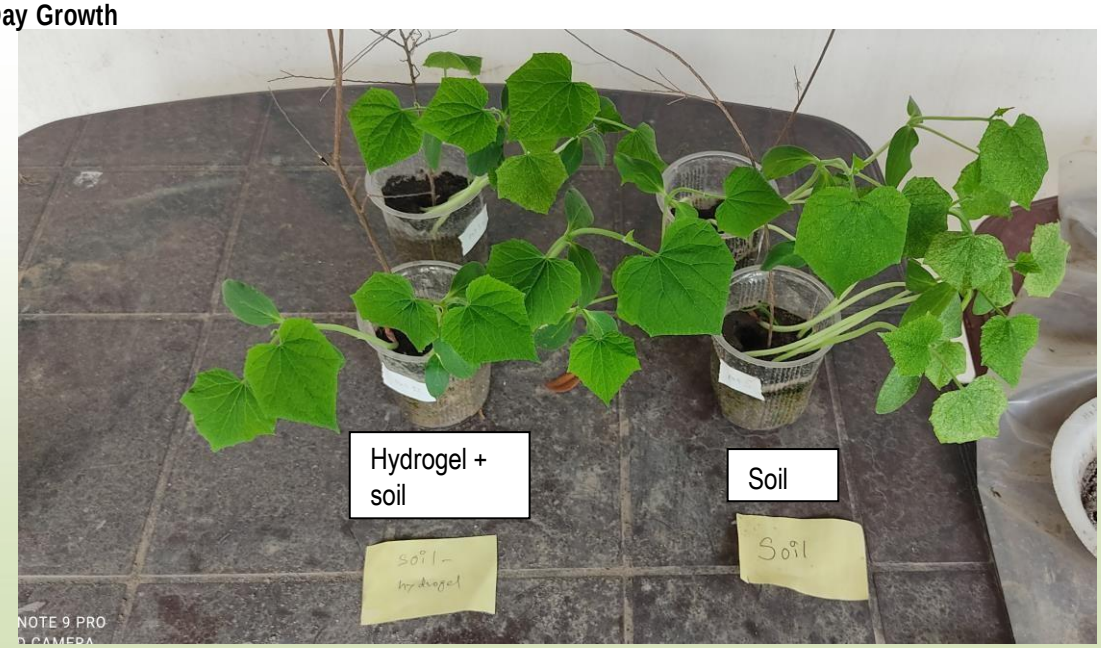
6th Day Growth



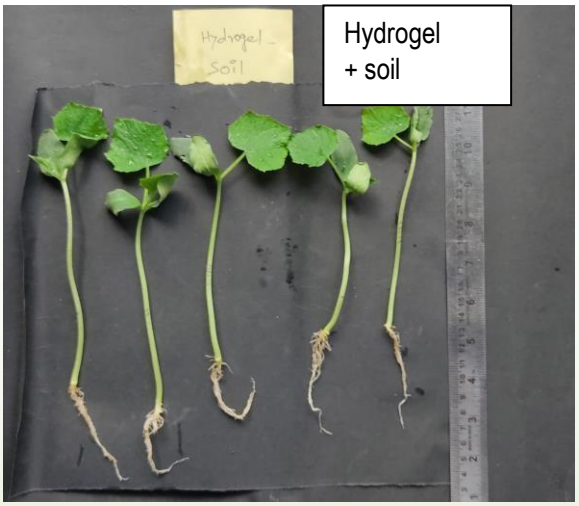
10th Day Growth

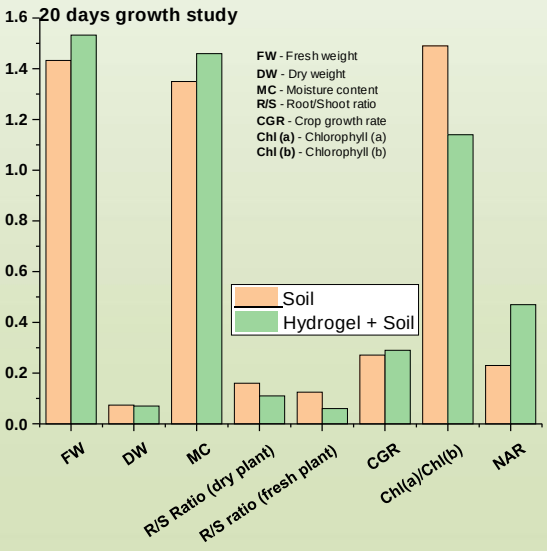
20th Day Growth

30th Day Growth



Step 5: Analysis of growth by different performance parameters





Data shows that hydrogel modified soil keep the soil moist for longer time as compared to non-modified soil, hence will reduce the irrigation frequency. Moreover, hydrogel modified soil has positive impact on plant growth as shown by different performance parameters in the graph.