Creating an Inexpensive, Effective Super Saturated Polymer Out of Citrus Polysaccharides

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The loss of water when farming constructs a significant environmental issue, as droughts evaporate 30% to 75% of agriculturally used water. Retaining the water in the soil is an essential environmental act, as minimized water loss would occur, therefore acting against water depletion. The objective of this project was to create an inexpensive and yet effective super absorbent polymer from cross linked citrus polysaccharides, using both oranges and avocados. A chemical system was constructed that included the crosslinking of 17 oranges and 14 avocados through a blending and heating process of sitting in an oven for 180 degrees celsius for 20 minutes. Once the three built super absorbent polymers; an orange juice solution, an orange juice, orange peel, and avocado mixture, and an orange peel and avocado mixture, were completed they were put into the soil boxes of 12 Ocimum Sanctum plants along with prebuilt super absorbent polymers, acrylic, pectin, and starch. For 22 days a soil moisture meter was used to take samples of moisture from each of the soil boxes and a ruler was used to measure the plant's height. Once found, the moisture levels, height, and number of leaves of each plant were placed into a data table on a Macbook, completing the experimental procedure. The combined mixture of orange peels, orange juice, and avocado peels stayed above a moisture level of 8 for 17 days and gained 2.03 cm of height proving that it was the most effective super absorbent polymer. This critical result was then achieved as only four leaves were lost for 16 days of testing. Creating an inexpensive yet effective superabsorbent polymer from crosslink citrus polysaccharides proved to be an effective objective and may change the future of farming.

Introduction

A drought is a specific hydrologic impact causing water users from one location to experience low water supply. When rainfall and the amount of precipitation is at a decreasing amount, streamflows decline causing water amounts in lakes and rivers to gradually fall. If dry weather such as an increase in heat or evaporation occurs, and the precipitation levels continue at the low rate, the period may end up in a drought[1].

My birthplace, California, is no stranger to drought as it is a recurring feature in our dry and volatile climate, but around 420,000 people have been internally displaced by drought in Ethiopia2. This means that approximately 7.4 million of these peoples are food insecure, causing 4.7 million children to face and come to terms with acute malnutrition[2].

When pondering about drought most people immediately think of water supply, as the significant and vivid image of lake water amounts dropping or even below ground water supplies decreasing, creates a sense of harm or surprise. But one of the most important and surprising effects of droughts is on crop yields and farming activities. The world's supply of water continues to make erratic and fluctuating changes, as it slowly decreases. Among that decrease, 30% to 75% of agriculturally used water evaporates before being procured by the roots of greenery[3]. This means that precipitation levels in farming soil needed for a significant crop yield are being decreased as the high temperature and parched weather conditions evapotranspirate water, dehydrating crops causing death[3].

Within this industry, there are specific products known as super absorbent polymers, or SAPs. These polymers can act as hydrogens and quickly and efficiently store water when contact occurs (over 300 times its weight in liquid), allowing them to be placed in agricultural areas, causing the water to be retained until it reaches the roots of plants[4]. These SAPs are significantly expensive. However, polymers are primarily made up of cross linked polysaccharides.

Orange peels contain over 63% polysaccharides, meaning that it shares a cohesive characteristic with SAPs, as polysaccharides allow the trapping of water molecules to occur, therefore creating a SAP[4]. However, the monomers in orange peels are not reactive, meaning that if avocado peels were placed into this experiment, the orange peels reactivity would become established, as avocados contain 54% natural oils[5]. The natural oil would allow emulsion polymerization to take place, meaning the monomers could react into polymer chains forming the reactivity needed for SAPs. This is due to the soil factor that natural oils contain amphili molecules, characterized by hydrophilic and hydrophobic regions, which enable them to act as surfactants. This means that when dispersed within water, the molecules align themselves at the oil-water interface, with hydrophilic regions facing the water and hydrophobic portions facing to the interior of the oil droplets.This arrangement reduces surface tension and prevents droplet coalescence, proving the ideal environment for the polymerization reaction.

The experiment stood alone in its focus on fruit based SAPs as other researchers pursued different avenues, seen in projects such as ”Investigating the Influence of Polymers on Supersaturated Flufenamic Acid Cocrystal Solutions’ ’ by Minshan Guo. While Guo’s work delved into the effects of polymers on supersaturated solutions of flufenamic acid cocrystals, the experiment in question concentrated solely on easily accessable SAPs.

SAPs found on market such as acrylic SAPs, starch SAPs, and pectin SAPs allow for an increase in positive water levels found in groundwater, however there are some generalities. Low polysaccharide numbers do not allow for maximum water retainability, and combined with increased prices due to severe California droughts, the SAPs have a low rate of work with a high rate of cost. Oranges are approximately $1.49 dollars per pound while a pound of pectin SAP is approximately $57.8 dollars, all while pectin based superabsorbent hydrogels combined with polyacrylonitrile were tested and were found to have an average rate of absorbance[6]. The solution of creating a cheap, effective SAP out of polysaccharides will be found through a significant crosslinking method combined with numerous rounds of testing.

My overall objective is to create an inexpensive alternative to modern SAPs, by using a natural crosslinking method in orange peels. This would theoretically allow water molecules to be trapped into the soil due to the citrus polysaccharides found in the samples.

Results

The idea of creating an inexpensive superabsorbent polymer out of crosslinked citrus polysaccharides, that is more effective than pre-created superabsorbent polymers, proved to be a challenge but the data proved my objective to be successful. Throughout the experiment the acrylic superabsorbent polymer seemed to be the most effective pre-created SAP and the orange peel mixture seemed to be the most successfully created SAP so a direct comparison between the two will be provided, proving the experiment’s success.

From day 1 to day 22 the moisture levels of the Acrylic SAP ranged from 10 to 4.8 and dropped from 10 to 9 at day 10. However, for the orange peel mixture, the moisture levels ranged from 10 to 5.2 dropping from 10 to 9 around day 15.

During the experimental process the average amount of leaves (between the two trials) of the acrylic super absorbent polymer ranged from about 24 leaves on day 2 to about 8 leaves on day 22. This means that 16 leaves were lost for an average of 0.8 leaves lost per day of testing since day 1. However, the orange peel mixture lost about 10 leaves from day 1 to day 22 averaging a loss of 0.45 leaves per day of testing since day 1, although for the first 8 days no leaves were lost, leaving the leaf remainder at a starting 20.

Along with the testing of moisture levels and the average amount of leaves, the height of the Ocimum Sanctum plants was also tested, showing the steady growth constant between each tested plant. On day 2 the plant with acrylic super absorbent polymer grew about 1.11 centimeters from 10.79 centimeters on day 2 to 11.9 centimeters on day 22. Although this showed steady growth, meaning the super absorbent polymer was successful, the orange peel mixture also experienced change. Starting at 13.97 centimeters on day 2 and ending with 19 centimeters on day 22, the ocimum sanctum plant containing the orange peel mixture super absorbent polymer grew 2.03 centimeters within the testing time span.

Discussion

A plant’s limited water supply might sustain them for up to 48 hours before the species starts to be affected by drought and hydration loss. The acrylic supersaturated polymers moisture levels dropped from 10 to 9 in 10 days meaning that enough water was retained in the soil for that amount of time to further nurture the ocimum sanctum before severe hydration loss, resulting in a loss of 16 leaves.

Although the data proves that the acrylic supersaturated polymer was successful, the orange peel’s moisture levels ranged from 10 to 5.2 dropping from 10 to 9 around day 15, meaning that even more water was retained in the soil further nurturing the ocimum sanctum for a longer period of time. This therefore resulted in a slower and lower loss of leaves, of 10 leaves from day 1 to day 22, averaging a loss of 0.45 leaves per day of testing since day 1, although for the first 8 days no leaves were lost, leaving the leaf remainder at a starting 20. The correlation between water retention and leaf loss is typically related to the plant’s ability to regulate water loss through transpiration. Transpiration is the process by which plants lose water vapor through small stomata pores in their leaves. When plants water uptake is decreased the leaf water percentage also decreases, resulting in lowered leaf productivity/ health. This results in leaves falling off which contributes to the overall death of a plant. Connecting to this research, because the plants that utilized the created SAP had less leaf lossage, they therefore absorbed a higher rate of water. In turn, because the orange peel mixture SAP held lower soil moisture levels, this means the tested plant variables absorbed the water that was utilized in the trials. Fortunately the weather during the testing period was mostly cloudy meaning that there were low productivity evaporation processes occurring.

Overall, the retained moisture levels and lower loss of leaves with a higher increase of height therefore proves that the cheap alternative, the orange peel mixture, was proven to be the most

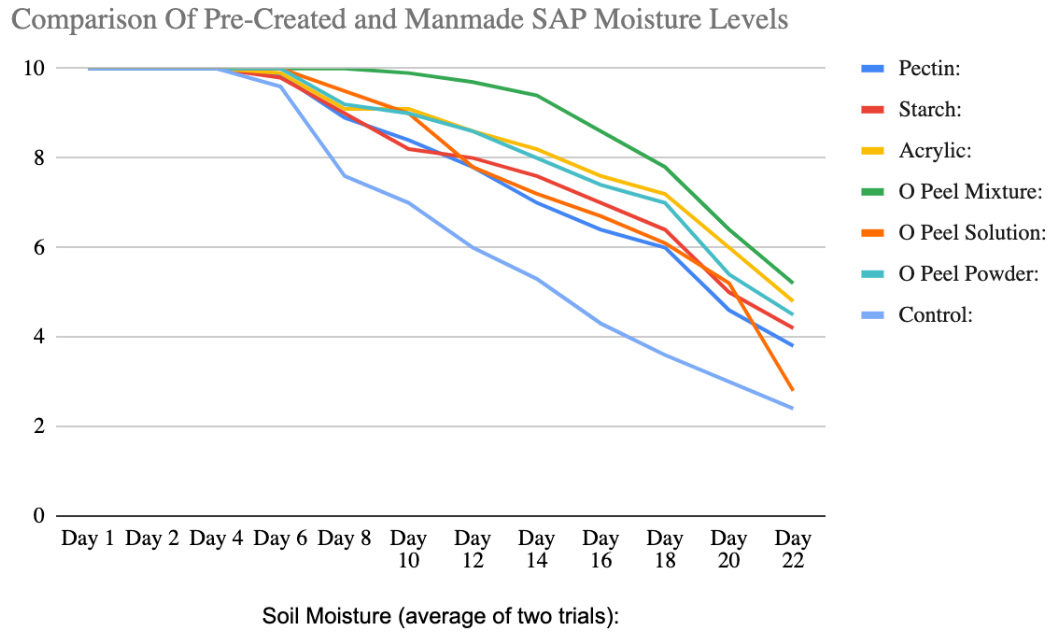

Fig. 1 The comparison of pre created and manmade SAPs on moisture levels, Credit: Gray Rappoport

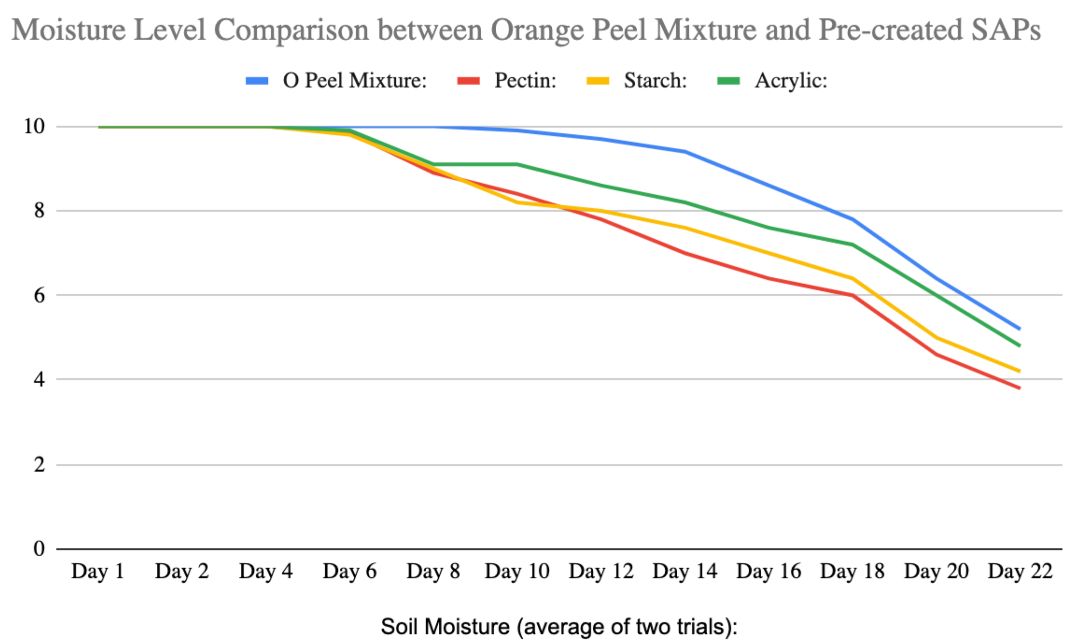

Fig. 2 The moisture level comparison between the orange peel mixture SAP and precreated SAPs, Credit: Gray Rappoport

effective supersaturated polymer, successfully completing my objective.

A future study that can be conducted is the testing of other acidic, polysaccharide based items such as lemons and even

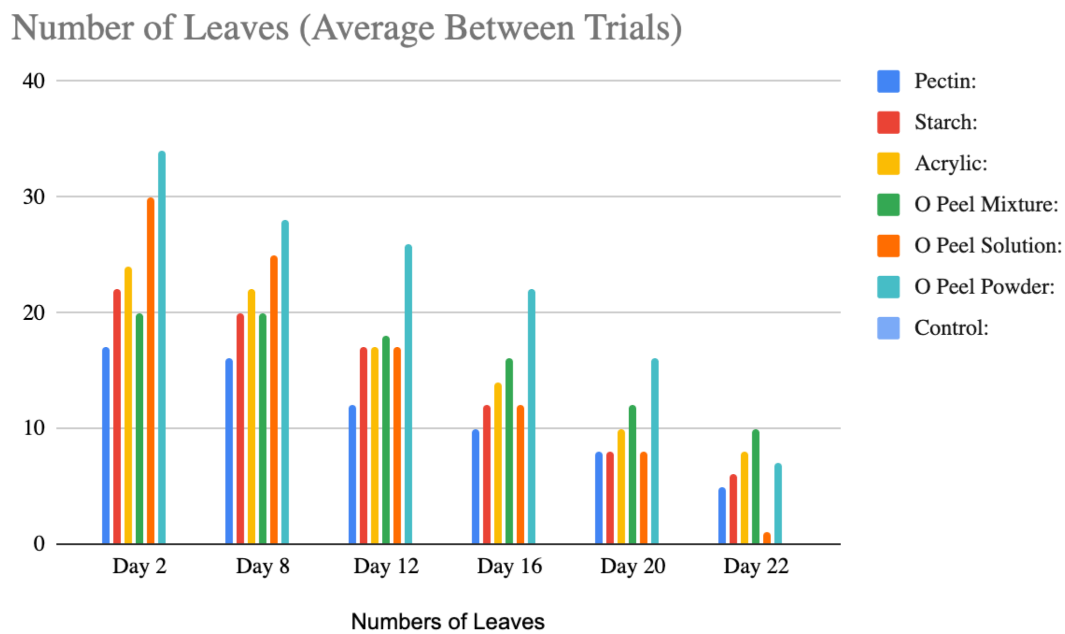

Fig. 3 The average number of leaves of an ocimum sanctum plant between trials, Credit: Gray Rappoport

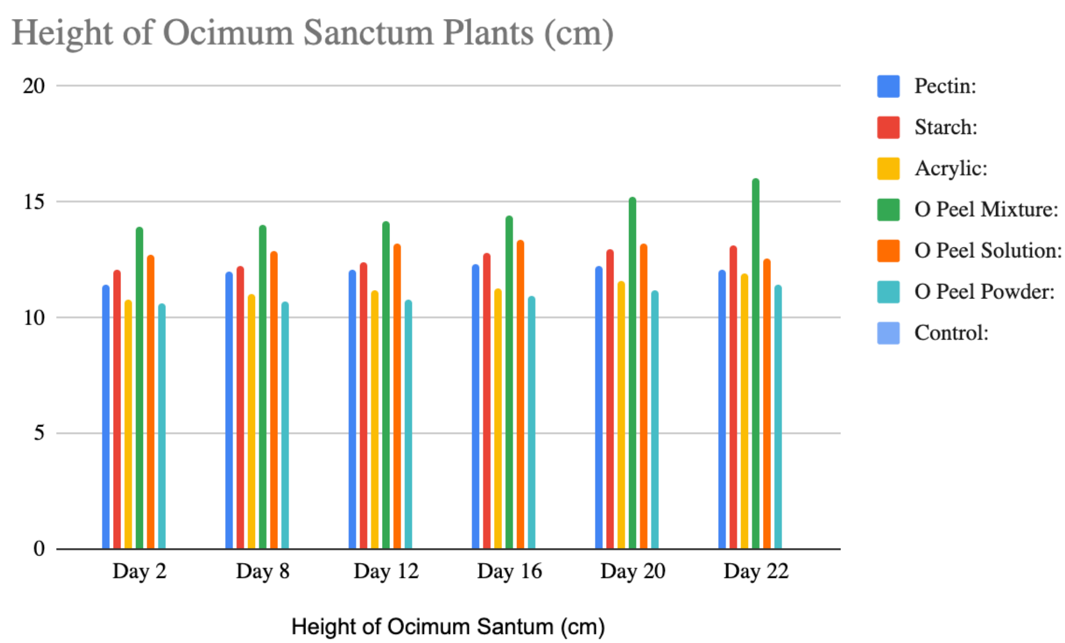

Fig. 4 The height of ocimum sanctum plants over the experimental days, Credit: Gray Rappoport

some household chemicals. In turn, there might be an even more effective, less expensive, solution to agricultural drought compared to the solution present in the tested experiment.

However, when investigating the effectiveness of soil amendment products (SAPs) on plant growth, the choice of sample size plays a critical role in the reliability of the findings. With only 12 plants, a small sample size may not adequately capture the variability among individual plants, leading to challenges in collecting connected differences in growth to the SAPs being tested. Variability in factors such as genetic makeup, environmental conditions, and human error responses can significantly influence plant growth outcomes, and small sample sizes may not accurately represent this variability. Additionally, the limited statistical power of small samples can hinder the ability to draw robust conclusions. To address these limitations, researchers should strive to use larger sample sizes whenever possible. By doing so, they can generate more reliable/ generalizable data that contribute to our understanding of SAP effectiveness, rather than external factors. Connecting to my own data limitations, the differences of height between the various tested plants maintain small scales, as the units are centimeters and millimeters. One must understand that a percent of these height changes could be contributed by the explained external factors such as temperature and sunlight. Moreover, recognizing these external factors is essential for accurately interpreting the data.

However, although more research can be done, the farming world might want to take up the idea of using orange peels as the polysaccharide base is not only healthy for the environment but is also more successful than the commercially available super saturated polymers

Methodology

Material

- Macbook Computer
- Latex gloves
- Plastic cover for table
- 17 oranges
- 100 ml of lemon juice
- A water source
- Stove
- Pot
- Knife
- 14 Avocados
- Oven
- Strainer
- Napkins
- Pan
- Baking sheet
- Starch base
- Acrylic acid (pH 1-2)
- Pectin base
- Sodium Hydroxide
- 10 same sized container (Preferred- 237 mL)
- 20 kilograms of soils (For Ocimum sanctum, which prefers well-drained soil, the optimal moisture level is generally within the range of 30% to 70% VWC)
- 14 pots
- 1 soil capacitance sensor moisture meter (Capacitance sensors operate based on the principle that the dielectric constant (or permittivity) of soil changes with variations in its moisture content. This change in dielectric constant affects the sensor's capacitance, which can be measured to determine soil moisture levels. The unit for the meter measures in volumetric water content (VWC))
- 12 Ocimum Sanctum plants (chosen for their adaptability to various soil types and climates, making it suitable for testing in any agricultural setting, rapid growth cycles, and ease of cultivation as they require minimal care and maintenance)
- Eye protection
- Ventilation hood

Methods

First three oranges will be peeled and the peels placed in 15 ml of lemon juice for 1 hour. The orange peels are placed in a pot filled with water (around 100 ml of water is placed with a handheld beaker to ensure even distribution). After, the peels are boiled for 45 minutes to 1 hour until liquid evaporation. Remove the peels from the pot and dry for excess liquid removal, allowing for an optimal SAP. Save the excess liquid as it will be used as variable "Orange Peel Solution" (60g of the liquid). After, cut up the peels into fine pieces allowing you to create an SAP powder in the end. Once completed skin 1 avocado. Cut up the avocados peel into extremely fine slices. Add the avocado skin to the orange skin and leave in the sunlight for 14 days. 90g of the dried orange and avocado skin has to be added to 80ml of the stored orange liquid and once done place the mixture into an oven at 180 degrees celsius for 20 minutes. This allows for a drying process to be created, creating a sample able to be grounded into a powder form. Take the mixture out of the oven and crush into fine powder. This is the variable "Orange Peel Powder " (60g used as the variable while rest is stored). Add 40 grams of the powder to 20 grams of the sun dried avocado peel and orange peel mixture creating the variable "Orange Peel Mixture". After, place the starch based, pectin based, and acrylic base SAPs into 6 separate containers (5 grams of each base with 200ml of water). Also place the three orange variables into 6 separate containers (five grams of each variable including the orange ones are used). Leave the samples for 10 minutes creating a rest state. Fill 14 pots with 1 kg of soil. Mix each sample into separate pots so each pot has one variable (25g of each variable). Leave two without variables, as they are the control groups. On the first day of testing water the soil with 100 mL of water. Every day for 22 days insert the moisture meter 4 cm deep into the plant at 6 different spots and average them out (Has to be at the same time each day; testing was completed at 7:00 A.M every day). When testing and calculating data use the formula: (Swollen sample weight-initial weight)/initial weight to calculate the water absorption). In the end follow the same steps but with Ocimum Sanctum plants instead of plain topsoil (Measure soil moisture, number of flowers, and height in cm for 22 days).

Fig. 5 Method Setup Photography (Taken by Author)

Safety Procedure

First place the eye protection over your eyes and place gloves and a lab coat on your hands and body. Then place a plastic covering over the table. After, handle the materials in a ventilation hood and when done place in a separate hazard bag and throw away. Then sterilize the space using paper towels and bacterial wipes.

Parental/ Overlook Procedure

Help the student with putting on the appropriate protection gear; gloves, eye protection, and a lab coat. Also assist the set up of variables and equipment in the experiment, all while monitoring the usage of chemicals. Your overall goal should be the Mediating of the students experiment.

Acknowledgments

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References

1 A. M. Torrado, *Brazilian Journal of Microbiology : [Publication of the Brazilian Society for Microbiology], Sociedade Brasileira De Microbiologia*.

2 S. California, *Drought. Department of Water Resources*, `https://water.ca.gov/drought`, Retrieved January 14, 2023, from.

3 Simon, *Everything About Super Absorbent Polymer*.

4 *What Is SAP – Superabsorbent Polymers*, `https://www.edana.org/nw-related-industry/what-is-sap`., Default,.

5 *Droughts: Facts, Causes, and How We Can Help*, `https://www.savethechildren.org/us/charity-stories/drought`., Save the Children,.

6 *Wikipedia, Wikimedia Foundation*.