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Abstract

Cotton discs with a blend of sodium alginate and germination compounds were blended into a hydrogel and planted with green onion seeds in order to determine a resulting increase of germination rate. After its product viability was determined, apparatus design was reevaluated to minimize seed suffocation effects with varied results dependent on disc thickness. Though the germination rates were lower than planting regularly, it is believed that if the gel's physical construction could more resemble soil, the suffocation factor would be negligible and drought tolerance can be more accurately measured.

Introduction

Sodium alginate hydrogel is a biodegradable, edible, low-cost anionic polymer prized for its rheological properties. It can be produced through alkaline extraction from brown seaweed Sargassum wightii in 1% formaldehyde and 2.5% sodium carbonate solution for a high yield of 31.7% alginate.[1] It does not always need to be synthesized from scratch because it's also easily purchased commercially in the molecular gastronomy field for its food gelation properties, making it a simple product to purchase and work with.

Alginate in general is a linear copolymer consisting of mannuronic acid (M) and guluronic acid (G) linked by 1,4-glycosidic linkages, creating the long chain structures that stabilize the seaweeds they come from. Sodium alginates are alginates created in a sodium solution, bridging the glycosidic linkages in single strands. When the sodium bridges are displaced by calcium, however, the linkages double with the increase in positive charge within the solution, making calcium alginate, a more rigid polymer. Typically, sodium alginate is mixed with aqueous calcium ions to enact the deeper crosslinking and thus make a rigid gel from a nonrigid liquid. However, this does not always need to be done in an aqueous environment.

Through creating a porous cotton casing filled with dry sodium alginate hydrogel and calcium salts, water could be soaked through dry layers in order to enact the gelation process within the layers entirely hands-free. This would enable agricultural applications underground where the chemistry can be applied only when desired.

The structure and background as an agricultural aid is based primarily upon the L/KJ/SA hydrogel soil additive of Bin Song, Hongxu Liang, Ruru Sun, Pai Peng, Yun Jiang, and Diao She[2]. This new hydrogel blend builds upon their mix of sodium alginate and konjac flour and alters its properties in order to be used as a disc form for the purpose of germinating seeds rather than something to be mixed into soil.

These changes are expected to aid primarily in germination, as bone meal additive is shown as an excellent support for this process and will be employed in place of the typical calcium lactate or calcium carbonate salts[3]. This should effectively offer enough nutrients for efficient germination while retaining a stable pH and providing enough calcium ions to begin the gelation process when it is watered. Due to the design of its casing, this supplies all nutrients essential to germination and initial growth until roots take place deeper within the soil underneath. With the womb-like nature of the apparatus, this supportive chemical filling will be enveloping seeds with a slow-release design inspired by sodium alginate's roles in drug delivery and medicine[4]. This product is abbreviated SA/BM for sodium alginate / bone meal.

Experimental Procedure

Seed Germination Efficiency

Design 1: Cotton Discs

Cotton filling is first pulled apart and shaped into thin discs of desired size, ensuring a level of thinness that can hold dry powders but also won't cage seed shoots. This was done to fit the shape of a plastic cup, roughly 4 inches in diameter, in order to fit the container that it would later be studied in. One of the discs is then dusted with 2.5g of dry sodium alginate powder evenly across the entire flat surface. 3.5g of nutritional bone meal powder is dusted on top of that, spread out manually if clumps are needed to be removed. Seeds can be added next, and due to the ease of germination, singular shoot setup, and quick growth time, green onion seeds (allium cepa) were chosen. For the sake of spacing, five seeds were added to each disc in a square shape with the fifth in the center of the square. Once these seeds are placed either by hand or with common tweezers, 2.5g of sodium alginate is dusted again on top. Another cotton disc of the same size can then be placed on top, pressing the ridges together. If the ridges do not combine easily, water can be applied via pipette and traced along the edges. Once the seed disc is completed, bacterial precaution needs to be taken. This is done by coating the top and bottom with household cinnamon or neem oil. Unfortunately, neem oil may interact with the dry powders inside the disc and requires further study, so cinnamon is used.

Lastly, the seed disc can be planted under soil and watered like normal. In this case, it was placed into clear plastic cups containing typical all-purpose potting soil to allow observation of the disc while it was buried. The soil should remain moderately moist without overwatering, so the containers were poked with holes at the start to allow drainage. This consequently means that the frequency of watering was closer to once every three days, watering only for a couple seconds at a time.

Next, for future experimental purposes only, the next fifty samples and fifty controls were done in a large blanket rather than the typical disc. This was completed through a dual system where a large planter box is filled with potting soil. In one half, the tri-layer seed disc synthesized in a larger size and planted with fifty seeds. In the second half, an even spread of fifty seeds is planted normally. This experiment is similar to the previous, the main difference being the combination of all fifty seeds in one sheet rather than five separate groups of ten. However, the increased size will also allow for larger growth and observation regarding growth patterns past seedlings in future experiments. This gives a sample population of 100 and a control population of 100.

Design 2: Paper Discs

After Design I was determined to be too thick for the seeds to germinate in, a second design was created with thinness and low durability in mind. This would effectively determine if thickness was the issue.

In this form, rather than cotton discs dusted with dry ingredients, paper towels are cut into 20 circles to fit their vessels. Then, half of the above SA/BM mix is made and homogenized in a dry phase. Next, this process differs by adding 240 grams of water to the bowl directly, stirring and letting the powders absorb all of the water until it becomes a slightly dense liquid.

Next, the 10 paper discs are soaked in the polymer gel, sandwiching 10 seeds between a pair each to make a sample of 50. This was compared to a more open-air sample where 5 paper discs are soaked and sprinkled with 10 seeds each. Lastly, a control was made where seeds were placed on 5 paper discs soaked in only water.

Drought Tolerance

Finally, the hundred samples in the cups were tested for drought tolerance. Once every stalk in the cups reached adolescence, watering simultaneously stopped, and they were kept out of wet environments. This data can then be compared to the drought tolerance reported in the SA/KJ/L hydrogel soil additive[2].

Results

SA/BM Cotton	Control
14%	74%

Figure 1: Comparison of allium cepa germination of SA/BM and normal planting, Design I

SA/BM Paper	SA/BM Open Paper	Control Paper
16%	34%	58%

Figure 2: Comparison of allium cepa germination of SA/BM and normal planting, Design II

Control Tolerance	Sample Tolerance
21 days	17 days

Figure 3: Days until stalk ‘death’ after ceasing water intake as deemed by the once upright stalks lying completely on the soil and beginning to brown.

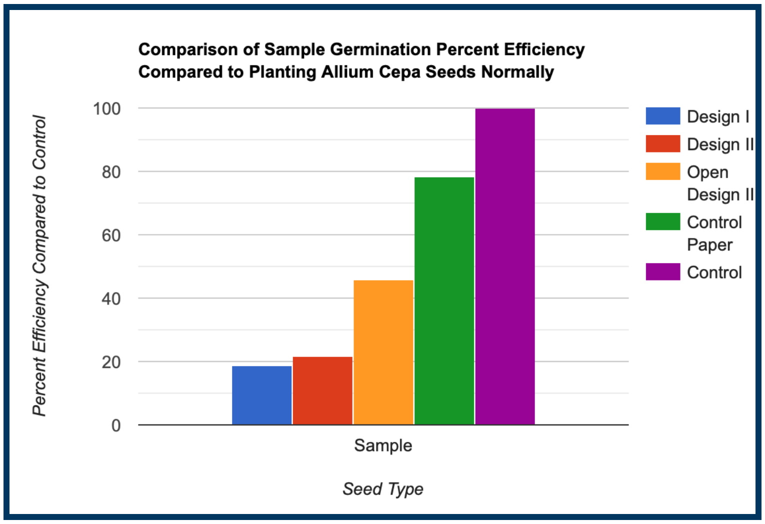

Figure 4: Comparison of each germination method as a percentage of control efficiency.

Discussion

Based upon the lower efficiency in germination rates of allium cepa seeds with the sodium alginate reagent mixture in the disc form, the sodium alginate seed disc design is not yet a viable method for commercial or recreational agriculture.

Figure 1 shows that for seed germination efficiency of sodium alginate hydrogel cotton disc (Design I), the rate of germination is 81% lower than planting in soil normally. This was determined by comparing the number of seeds successfully germinated from the seed disc cups plus the planter and the seeds successfully germinated from the normal cups and planter, easy to tell due to the single-stalked nature of the allium cepa sprouts. All other sprouts were removed by hand. This failure was likely because they both lacked oxygen and a loose aerated area, which could be fixed if made much thinner and less saturated with gel. This inspired design II.

In design II, the suffocation factor was tested by planting discs done in an open-face fashion and compared to a control and a sandwiched-style application. The open-faced discs, though 41% lower efficiency than the control, were seen to be 113% higher than the sandwiched discs. This illustrates the suffocation factor is prominent and needs to be altered in order to effectively germinate future seeds.

Additionally, the difference in paper control and the cotton control (seeds planted with a wet paper towel versus completely normal) showed that the paper control had about a 22% decrease in efficiency without any chemical difference. This illustrates the importance of an effective rooting system in allium cepa germination.

The drought tolerance testing was inconclusive due to the difference in stalk health. Sample stalks, taking days longer to germinate than the controls, were also often thinner than the control stalks. This implies that their drought tolerance could not be directly compared to the thicker hardier stalks in the control. In additional testing, this part could not be completed until the germination had similar timeframes compared to control seeds and the resulting sprouts looked to be nearly identical to each other as well. Additionally, the data collected for drought tolerance was merely the average time it took for death, and with a smaller living sample size of the sample sprouts, this data signifies no real attribution towards the seed discs or their properties. This means that the comparison of these results to other studies are no longer applicable.

Conclusion

The suffocation of seeds within the disc apparatus was one of the primary contributors to a slower and less efficient germination, with an improper rooting system contributing as well. This made studying drought tolerance or crop growth effectively impossible to compare as the seeds grown from the sample were entirely less healthy overall from the start. It is then believed that if the suffocation of the apparatus was cleared and air could travel more freely to the seeds, this issue would be fixed.

However, the decrease in allium cepa germination efficiency correlating to thickness of a hydrogel showed a clear relationship that can be used for other suffocating environments. Though the object of this research was to determine a way to germinate seeds more efficiently, it has been shown that packing of aqueous polymer gels decreases efficiency and overall plant health. This may also correspond to other dense or packed soil environments.

Future Research

A mesh lattice made of paper can be purchased readily online. This material can act sort of like a net that can be dipped into a SA/BM solution, using the surface tension of the dense liquid to create thin layers of material throughout without having any suffocation from above or below the gel. This may be called the bubble blowing method as it shares a similarity to the thin film that rests between the plastic of a bubble-blowing wand. This paper material should also have a low biodegradability time and should not hinder any germination or growth if the paper is as untreated and undyed as possible. Additionally, the percentage of additives in the solution will be experimented with further as to examine the possibility of overbearing the seeds with nutrients and hindering growth in that form.

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