Arid Plants Mask Drought: *Exploring the Effects of Varied Amounts of Natural Polymer Hydrogel in Enhancing Drought Resistance in Canola*

Testable Question: Do the Different Amounts of Natural Polymer Hydrogel Enhance Drought-Resistance in Canola Plants?

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Mentor: Mrs. Aulakh

Project Type: Experimental

Project Category: Life Sciences/Botanical Sciences

Grade: 9

Year: 2023-2024

TIMETABLE:

Date of Task	***Description of Task***
November 10th, 2023	**Deciding Testable Question:** Met with Mrs. Aulakh to finalize a list of topics for the Science Fair browsed through the following topics and viewed the pros and cons of each potential project: ● *Exploring the effects of ethanol on drought resistance in plants* - **Reason(s) didn't choose as my final testable question:** The project involves the use of ethanol which is flammable and requires special permission. Ethanol is considered a volatile organic compound ● *What is the most effective method to resist pathogen-based diseases in plants?* - **Reason(s) didn't choose as my final testable question:** Requires access to sophisticated equipment, no access to "pathogen-based" diseases to implore the experiment further, and would ultimately become a research project due to lack of materials, therefore not being a string Science Fair project ● *Do the Different Amounts of Natural Polymer Hydrogel Enhance Drought-Resistance in Canola Plants?* ***- Final Testable Question***
November 11th, 2023	**Finalization of Testable Question:** I met with Mrs. Aulakh and asked her to ensure that the topic is doable according to my grade level and meets any other criteria of a testable question. This process took a lot of thinking as each project had to be seen with durability, and credibility, all per my school and CYSF guidelines. **Finalized testable question:** *Do the Different Amounts of Natural Polymer Hydrogel Enhance Drought-Resistance in Canola Plants?*

November 11th-23rd, 2023	Read through and watch every link under the "FAQ" section of CYSF's page. Outlined what I will be doing for each step of my experimental project. I watched a few videos regarding my question but realized I should begin with a basic understanding of my experiment.
November 23rd, 2023	Created a list of video links, websites, and books about my topic. No summary besides them, just general information about what my project was going to look like and how to make it come together. **LINKS/URLS/WEBSITES/VIDEOS RELATED TO MY TOPIC** • https://www.who.int/health-topics/drought#tab=tab_1 • https://www.canolacouncil.org/research-hub/canola-lines-with-increased-heat-drought-tolerance/#:~:text=Overview • https://link.springer.com/referenceworkentry/10.1007/978-3-030-76523-1_5-1 • https://doi.org/10.1016/j.envexpbot.2020.104055
November 24th, 2023	**Completion of Hypothesis and Variables (Part of the Scientific Method) and Started Background Research for Experiment:** **PHOTOSYNTHETIC FLOTATION AND ET (EVAPOTRANSPIRATION)** ○ Did research on photosynthetic flotation *(a way to measure the rate of photosynthesis)* and ways to measure drought ○ Looked at the research behind this and its' credibility ○ **Findings on parameters to measure drought resistance in plants:** Root length, photosynthesis, and leaf water retention ○ Discovered that more expensive methods to measure leaf water retention wires out of my budget as a tensiometer *(a device that measures water retention)* costs $5000-$2000 and a thermocouple psychrometer *(a device to measures the relative temperature of the air)* costs CAD $500-$700 ○ I accounted this as something I would add to my *"What would you do differently?"* as the instruments have far greater accuracy and more sophisticated methods ○ After researching the fundamentals of the experiment, I started to look for the materials e.g. hydrogel, milligram scale, needless syringe, and many more *(refer to "Materials" section to view all the materials used in the experiment)* **I tried contacting some students at the University of Saskatchewan to seek access to instruments, but unfortunately, I couldn't due to certain reasons.**

URLs used for Photosynthetic Flotation Research:

- https://agriinfo.in/measurement-of-drought-resistance-in-plant-breeding-2128/
- https://www.frontiersin.org/articles/10.3389/fpls.2017.00721/full
- https://www.exploratorium.edu/snacks/photosynthetic-floatation
- https://www.sciencebuddies.org/stem-activities/photosynthesis-floating-leaves

RWC (LEAF RELATIVE WATER CONTENT)

- Formula: (Fresh weight – Dry weight)/(Turgid weight – Dry weight) × 100
- RWC is a crucial indicator of water balance in the leaves of plants
- Acts as a parameter used to test drought resistance of certain plant species (common method used among scientists)
- In simple terms, higher RWC means more drought resistance as there is more water in the leaves despite the drought conditions
- Thought that this was an exceptional parameter to enhance data to test for drought resistance

URL for Research on RWC:

- https://www.youtube.com/watch?v=uyUYFKnaAnk

ROOT LENGTH OF THE PLANTS

- Length of the plants shows drought resistance as they are a direct indicator of plant productivity
- Not the main indicator of showing drought resistance but has been proven helpful in many studies
- Shows effect of drought on plants

URL Used to Research Root Length

https://agriinfo.in/measurement-of-drought-resistance-in-plant-breeding-2128/

	Realizing I needed to check all the right conditions I needed to make this experiment as realistic as possible. Sections included: **1.** pH and EC of water **2.** Type of soil **3.** Amount of water **4.** Temperature
November 25th, 2023	**<u>Started going over ideas for "What's Next?"</u>** - Further topics relating to drought resistance - Explore new topics; maybe contact someone who has access to pathogen-based diseases in plants. - High-salinity or wastewater recycling alternatives to avoid excess irrigation - Find ways to make an accessible database to share planting information from botanical experts: I have always found finding information e.g. what is the best EC for radish plants, wheat, etc a hassle - I want to change the scope of viewing agriculture as a field of Science that can compete - Increase knowledge of agriculture (especially Alberta) across the world via a database (app, website, or any other social platform) - Develop replicas of instruments such as thermocouple psychrometers and make them affordable and accessible to people who want to use these instruments
November 25th, 2023 - November 30th, 2023	Ordered the materials for the experiment to ensure there was no delay. The list of all of the materials used in the experiment can be seen in the "Materials" section. For inference, some of the materials included a needless syringe, milligram scale, single-hole puncher, and more. Some materials were regular household items such as baking soda, dish soap, soil, a pencil, etc.

December 1st, 2023	Completion of the Procedure *(Part of the Scientific Method)*
December 1st-December 22nd, 2023	Started opening documents for my Science Fair project: - Google Slides presentation ○ I couldn't do too much for it as the actual information was to be added at the start of my growth period for the canola seeds ○ Meanwhile, I took note of the major articles and began my "Works Cited/References" page to avoid any unwanted plagiarism ○ Put together all the research on a Google Document and asked Mrs. Aulakh some questions in regards to the hypothesis Realised there were a few mistakes with the hypothesis and tweaked the mistakes with Mrs. Aulakh's help.
December 22nd, 2023	Realised I needed to work fast with my germination process and researched the time to soak seeds in water which was 24 hours. I accounted for this as data and continued researching. I realized the things I ordered were going to come on January 7th (very late), but I had time until the plants would be three-fourths mature, which was adequate growth needed for my experiment.
December 23rd, 2023	**Finished my planning for my project and figured to start the parts of the CYSF platform that I could.** **Completion of Ethics and Due Care 2A and Basic Project Information on the CYSF platform** (done before the given date: March 15th to ensure the timeliness of the project is as efficient as possible)
December 24th, 2023 - December 28th, 2023	Couldn't work on the Science Fair due to a family emergency abroad.
December 30th, 2023	**Conducted the Floating Leaf Disk Assay Experiment (Photosynthetic Flotation) to ensure the Experiment would work with the Canola Leaves** ○ Tested the experiment with spinach leaves and the experiment worked as the leaves started floating ○ Fascinated by the method and continued experimenting with it a couple of times to ensure it wasn't a fluke

	○ Realised the reliability of the method as it seems to be a great addition to measuring drought resistance in plants **URLs Used to Conduct the Photosynthetic Flotation Experiment to ensure the Method is Reliable:** - https://www.exploratorium.edu/snacks/photosynthetic-floatation - https://www.sciencebuddies.org/stem-activities/photosynthesis-floating-leaves
December 31st, 2023	**Completion of all the Background Information** ○ Did research on more parameters to test drought resistance and came to a dead end as once again, it required the use of expensive instruments **ENCOUNTERED A HELPFUL WEBSITE AND VIDEO:** https://sherubtsebotmal.wordpress.com/2021/03/18/aim-to-measure-the-of-relative-water-content-rwc-in-plant-tissue/ https://www.youtube.com/watch?v=uyUYFKnaAnk ○ This website ensured the RWC by giving me a range of websites proving that RWC measured drought resistance ○ Had practicality and evidence that RWC worked and could be calculated through a series of steps ○ Showed data of plants which seemed accurate as multiple sources (including the ones' mentioned) similarly say the same thing From this point I believed my research on parameters to measuring drought resistance was complete and later focused on the scientific method aspect of my experiment
January 6th, 2024	Soaked the 24 canola seeds in 100 mL of water for 24 hours to speed up the rate of germination of the seeds. **The time I soaked the canola seeds:** 8:00 am

	I waited till the next day at 8:00 am to drain the seeds and plant the seeds into the soil to ensure the period soaked was the same as the one mentioned above (24 hours).
January 7th, 2024	Started the growth period of the canola plants *(refer to the "Picture in the Procedure" and "Procedure" for information pertaining to the growth period of the canola seeds)* *Took out the seeds at 8:00 am. I got the grow trays ready and poured 1030 g of soil in each of the 4 trays. Then, I placed the seeds in the soil at a distance of 3 inches from one another. Next, I sprayed 150 mL of water uniformly (with a spray bottle) on the soil bed to stimulate germination. At last, I turned the two LED plant lights on to the setting of 12 hours ON and OFF.* *After this, I had to record the data for any growth and take note of it in a notebook and my Excel sheet.* I took a picture during this and added it under "Procedure" and "Pictures During the Procedure."
January 7th, 2024 - January 9th, 2024	**NO GROWTH OF ANY OF THE SAMPLES** - Accounted the height of the plants as an average as the graphs would not look accurate or readable with 60 columns in the x-axis. I finally decided on how I should account for height! - Figured to also add a table on an Excel sheet, table (notebook), and on a table on this Logbook document - Waited patiently for the canola plants to grow - Took note of the number days it took the seedlings to sprout
January 10th, 2024	**THE CANOLA PLANTS GREW (FASTER THAN EXPECTED!) - GERMINATED ON THE THIRD DAY OF BEING TRANSPLANTED IN THE SOIL** A few seedlings started to pop out of the soil and I noted down the average height and accounted for it as data. The following heights were: **SECTION 1:** 0.06 cm **SECTION 2:** 0.07 cm **SECTION 3:** 0.06 cm **SECTION 4:** 0.06 cm

January 11th, 2023	The canola plants continued to grow and I continued to take data. To sum up the notes, 50% of the samples sprouted to my dismay. This was good news as this was an indication of the right environment for the seedlings. The following heights as per the section were: **SECTION 1:** 0.3 cm **SECTION 2:** 0.29 cm **SECTION 3:** 0.28 cm **SECTION 4:** 0.3 cm From the results, you can tell there is minimal difference between every section.
January 12th, 2024 - January 20th, 2024	I noticed that the canola samples were growing approximately 0.5% a day. The pigment is a dark emerald green which shows healthy samples (good conditions). Some were light green. This was the same for January 12th - 16th, 2024. - Same as usually I record the heights and the pigment of the leaves which were all surprisingly emerald green (refer to pictures - Leaf size got bigger (big enough for the R.W.C. and photosynthetic flotation, but not mature enough)
January 21st, 2024 - January 24th, 2024	The canola samples continues to increase in height (refer to the average height logbook in regards to how much they grew) Same observations as January 21st - 24th with an exception of the increase in leaf count and average height The leaves were big enough in size and quantity **January 25th, 2024** - Last day of growth period (20 days for all the canola samples)
January 26th, 2024	Started the drought stimulation period for a period of 10-days No visible changes could be seen in the height or the colour of the leaves nor the average leaf count of the samples The same canola plants from the 24th of January can be seen in the samples Same average height and leaf count as January 25th

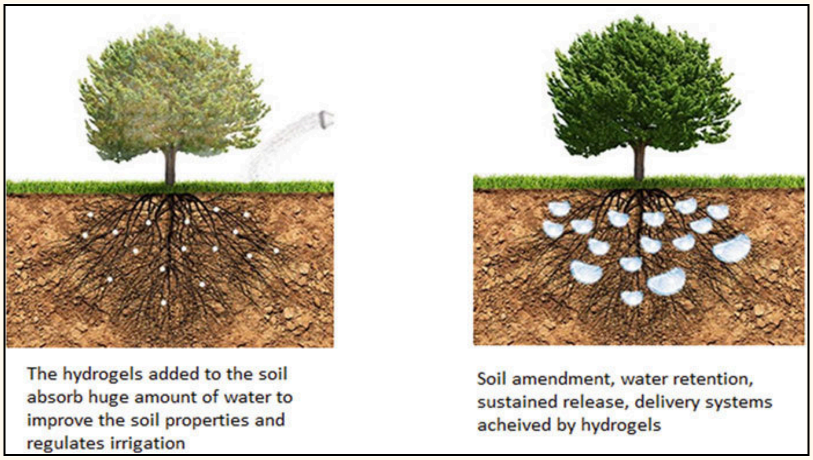
January 27th, 2024 - January 30th, 2024	Average height and leaf count of the plants increased very slowly (most likely due to the drought stimulation period also while considering the lack of maturity of the samples) Pigmentation of plants declined (visibly) Observations can be seen in the "Observations" section of the document
January 31st, 2024 - February 6th, 2024	**Last Day of Drought Stimulation Period and Hydrogel Application (One-time application) - Feb. 6th** Waited for the 12-hour lighting period of the plants to be over and started to conduct the actual data of the experiment Recorded the R.W.C., photosynthetic flotation, average leaf count, height, and root length of all the sections and accounted that as data and added them to graphs As per my hypothesis, through all metrics, Trial 1 was favoured as it was the recommended (backed by research) Compiled the statistical data, graphs, conclusions, and final observations which took a pretty long time but at the end, the results were promising More details on results can be seen in the logbook/lab report/statistical data/google slides presentation as the actual sections provide the hard, concrete data of the experiment Printed out my lab report and logbook, as per the expectations in the criteria for the Science Fair Rehearsed and timed my presentation for the school-wide Science Fair which had to be equal to or less than 10 minute **IN SIMPLE TERMS, FINALLY, THE EXPERIMENTATION OF THE PROJECT WAS DONE AND THERE WAS PROMISING DATA EXPORTED FROM THE VARIOUS METRICS TESTED**
February 1st, 2024 - March 1st, 2024	**Started experiment again as Mrs. Aulakh advised me to as she was preparing me for the CYSF** - Improved data by increasing growth period to 30 days and drought stimulation period to 7 days or a week to improve my data and the validity

	- Data can be seen in the Data/Observations/Graphs/Tables shown in my logbook via qualitative and quantitative data
February 6th, 2024	In-class took place at Khalsa School Calgary - Got selected in the top 5 to continue to compete for the school-level Bronze, Silver, and Gold medals!
February 7th, 2024	The Final Judging took place where judges/parents from outside were called to judge the projects and spectate them as well - Got the results the same day and realized I won first place in my class and would officially enter the CYSF in my school!
February 8th, 2024 - February 20th, 2024	- Started filling up information on the CYSF online platform Enhanced statistical data via EEI
March 2nd, 2024 - March 9th, 2024	Took observations and conducted the 1 week doubt stimulation period where all samples weren't given any irrigation water, and were only under constant sunlight for all Observations can be seen in the logbook by seeing the observations and the qualitative and quantitative data as well
March 10th, 2024	Compiled my logbook and made all necessary observations and formulated a conclusion from my 30-day growth period and 8-day drought period
March 11th, 2024	Recorded my video for the CYSF platform - Posted everything on a tri-fold decorated it and ensured everything was correct on it
March 12th, 2024 - April 10th, 2024	Prepared for the in-person CYSF fair at the Olympic Oval and rehearsed questions that I looked up on the "FAQs" on the CYSF website
April 11th, 2024	Set-Up (Trifold set up, no experiment set up) at the Olympic Oval at the University of Calgary
April 12th, 2024	CYSF Judging Day at the Olympic Oval at the University of Calgary
April 13, 2024	CYSF Medal and Award Ceremony at the Olympic Oval (University of Calgary)
END OF THE TIMETABLE OF THE EXPERIMENTAL PROJECT	

BACKGROUND RESEARCH

(Refer to the "Works Cited" Page for the Citations being referred to in the Background Research)

What is a Natural-Based Polymer Hydrogel in Plants?



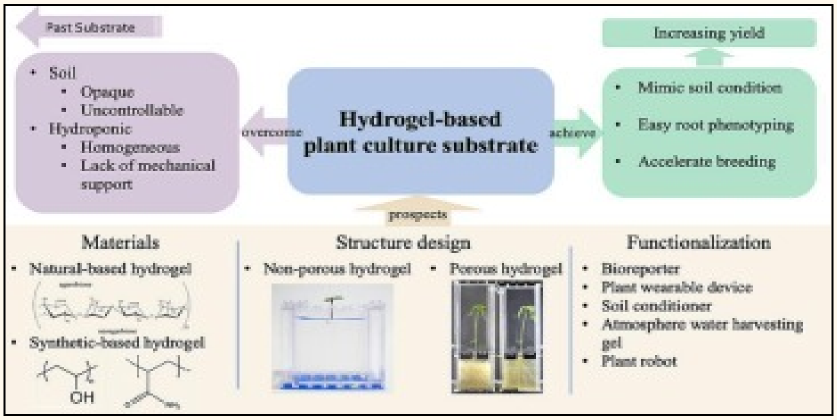
"Superabsorbent polymers (hydrogels) have been researched as potential soil amendments that could help improve soil hydraulic properties and make water more available to crops, especially in their critical growing stages…" (Adjuik et al., 2022). In simple terms, hydrogel is a conditioner for plants because of its water retention properties leading to longer periods without irrigation.

FIG. 1 - Springer Journals. (2021). Application of Hydrogel and its' Water Retention Properties [Web *Application of Hydrogel and its' Water Retention Properties*]. In M. Mostafa, M. El-Sayed, & A. Sayeed (Eds.), *Springer Link*. https://link.springer.com/referenceworkentry/10.1007/978-3-030-76523-1_5-1

How does a Natural Polymer-Based Hydrogel Help in Drought Resistance in Crops?

A natural polymer-based hydrogel is a sustainable solution to mask drought resistance in not only canola but many other crops via its water retention properties and galore. "Hydrogels increase the soil's ability to hold water while lowering evaporation, leaching process, and runoff. They also increase plants' uptake of water and its availability, mainly during drought conditions, by enhancing aeration, porosity, soil structure, and biological activity of soil" (Tariq et al., n.d.). Therefore, a natural-polymer hydrogel aids crops in drought resistance through its water intake properties; much needed during drought conditions.

Why is Natural Polymer Hydrogel being used as Opposed to Synthetic Polymer Hydrogel?



In recent years, a growing problem of water deficit has been observed, which is particularly acute for agriculture. To alleviate the effects of drought, hydrogel soil additives-superabsorbent polymers (SAPs)-can be helpful. Both kinds of soil amendments (synthetic and natural) similarly improve the yield of crops. In the case of natural origin polymers, a lower cost of preparation and a shorter time of biodegradation are indicated as the main advantage in comparison to synthetic polymers, and greater security for the environment" (Grabowska-Polanowska et al., 2021). On the other hand, synthetic polymer hydrogel produces sludge as a by-product and has a lower chance of biodegradability as compared to natural polymer hydrogel.

FIG 2- Ma, L., Chai, C., Wu, W., Qi, P., Liu, X., & Hao, J. (2023). Hydrogels as the plant culture substrates: A review. *Carbohydrate Polymers*, *305*, 120544–120544. https://doi.org/10.1016/j.carbpol.2023.120544

Functional Characteristics of a Hydrogel
(i) The high water absorption capability (ii) The desired rate of absorption and desorption capacity according to plant requirement (iii) Lowest soluble content and residual monomer (iv) High durability and stability during swelling and storage (v) High biodegradability and biocompatibility (vi) High performance over a wide temperature range (vii) After swelling, water becomes neutral in pH (viii) Colourlessness, odourless ness, and nontoxic (ix) Upscale the soil's physical, chemical, and biological properties (x) Photostability, rewetting capability for a longer time, low-cost material, and eco-friendly
Credits: Sanjay Kumar Patra, Poddar, R., Brestic, M., Pravat Utpal Acharjee, Bhattacharya, P., Sengupta, S., Pal, P., Nyape Bam, Biswas, B., Viliam Barek, Ondrisik, P., Skalicky, M., & Hossain, A. (2022). Prospects of Hydrogels in Agriculture for Enhancing Crop and Water Productivity under Water Deficit Condition. *International Journal of Polymer Science*, *2022*, 1–15. https://doi.org/10.1155/2022/4914836

Classification of Hydrogel:

"The three varieties of hydrogel for agricultural usage are (i) natural hydrogel, (ii) semi artificial hydrogel, and (iii) artificial hydrogel, according to the source [21]. Under their chemical makeup and structure, the petroleum-based synthetic or artificial hydrogels that are currently on the market are primarily divided into three distinct categories:

(i) Starch-polyacrylonitrile graft polymers (starch copolymers)

(ii) Vinyl alcohol-acrylic acid copolymers (polyvinyl alcohols)

(iii) Acrylamide sodium acrylate copolymers (cross-linked polyacrylamides)" (Sanjay Kumar Patela et al., 2022)

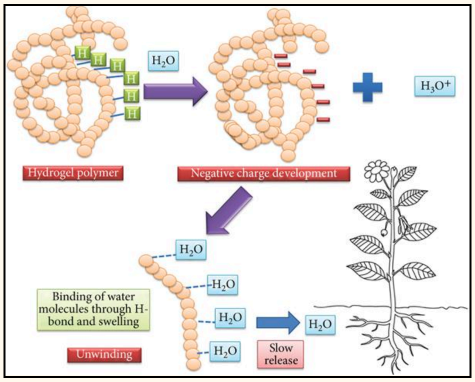
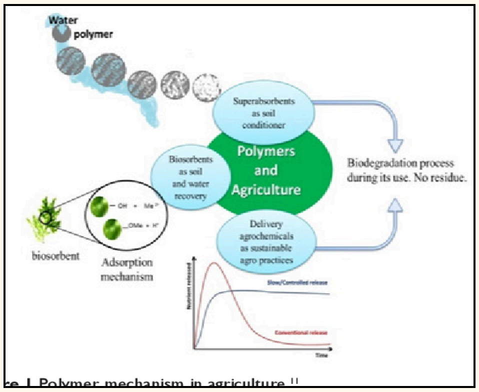


Figure 1 - Mechanism of action of hydrogel upon soil-based application. Sanmay Kumar Patra, Poddar, R., Brestic, M., Pravat Utpal Acharjee, Bhattacharya, P., Sengupta, S., Pal, P., Nyape Bam, Biswas, B., Viliam Barek, Ondrisik, P., Skalicky, M., & Hossain, A. (2022). Prospects of Hydrogels in Agriculture for Enhancing Crop and Water Productivity under Water Deficit Condition. *International Journal of Polymer Science*, *2022*, 1–15. https://doi.org/10.1155/2022/491483

Why are Natural Polymer Hydrogels a Sustainable Solution to Mask Drought Resistance?



"The current climate changes are felt at the global level through two primary consequences, namely the increase of day and night temperatures and the decrease of water availability, a fact that determines an important impact in the practices of cultivating plants. Due to this reason, superabsorbent materials such as hydrogels, have been developed to be used especially in plant cultivation systems. The practical relevance of the use of hydrogels in plant substrate could lead to an improvement of water and nutrient management conditions in the field of agriculture. Hydrogels act as a reservoir of water and/or nutrients with gradual release according to plant requirements and in a controlled manner. Thus, a favourable environment for the development of roots and plants is created and maintained throughout their growth" (Grabowska-Polanowska et al., 2021). "Natural polymers derived from materials in the natural world, such as polysaccharides and proteins, have a good biocompatibility and biodegradability, making them an ideal choice for the fabrication of hydrogels" (Zhao et al., 2023).

W. Abobatta. (2018). *Impact of hydrogel polymer in the agricultural sector*. https://www.semanticscholar.org/paper/Impact-of-hydrogel-polymer-in-agricultural-sector-Abobatta/adbfa5c84e4a61f05b1ecb89c830b11692f8b9f3

How did I Decide the Amount of Hydrogel for Each Section?

Section 1: 2580 mg in 1030 cm cube	*Section 2: 4000 mg in 1030 cm cube*	*Section 3: 1000 mg in 1030 cm cube*	*Section 4: Constant (0 mg Hydrogel in 1030 cubic cm)*
It was the recommended amount for all crops, therefore making me choose this as not only my hydrogel but my hypothesis. This was backed up by research which can be seen in the hypothesis too.	I wanted to see how excess amounts of hydrogel would impact the growth. Would the growth be maintained, improved, or worsened?	Vice-versa of the 400 mg, I wanted to see how excess amounts of hydrogel would impact the growth. Would the growth be maintained, improved, or worsened?	This was to compare the impact of hydrogel on canola samples as compared to canola samples left untreated with anything, which aligns with the situation of treating today's "*drought prevention.*"

Why are Canola Plants Being Used as a Crop for this Experiment?

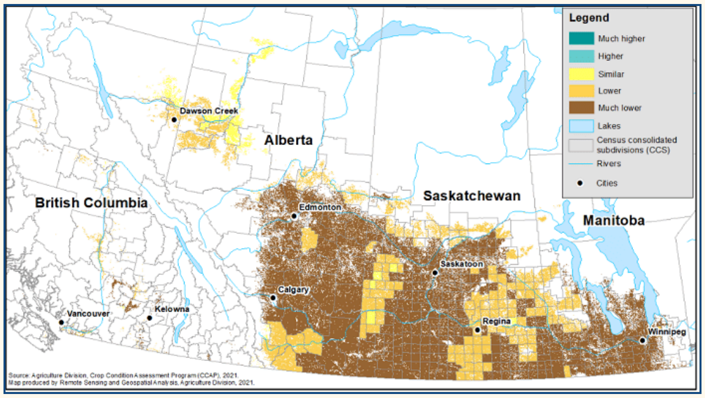
This crop is not being used just for the sake of being one of Alberta's most produced crops and favourable amongst farmers. "Heat and drought stress can have a severe negative impact on canola. Recent extreme heat waves and arid conditions in Western Canada have led to catastrophic yield losses of canola in some areas. Based on projections of global warming, these events are only likely to worsen in coming years, and without mitigation procedures, crop losses will be inevitable" (*Generation of Canola Lines with Increased Heat and Drought Tolerance by Regulating Phospholipid: Diacylglycerol Acyltransferase Activity*, n.d.). The canola crop is one of Alberta's crops that needs a sustainable solution to mask the agricultural drought it is facing.

FIG 3 - The Western Producer. (1 C.E.). Canola Plants facing Drought in Southwestern Alberta [Web *Canola Plants facing Drought in Southwestern Alberta*]. In R. Arnason (Ed.), *MDPI*. https://www.producer.com/news/flash-droughts-can-pose-risk-to-crop-production/

Is Canola a Drought Resistance Crop?

Canola crops are no exception to not facing drought; like many other crops in areas in Alberta and beyond, canola is also susceptible to drought. Canola is one of those crops that faces the most distress during droughts, health-wise and financially for farmers as well.

Canola Yield Over Drought Period - Much Lower than Past Years



From this source from the government of Canada, it can be seen the moisture level of Alberta (and other neighbouring provinces) has been less and decreased significantly throughout the past years in not only canola but many other crops as a whole. This also becomes another reason behind this project in finding a feasible solution to mask drought resistance in crops via hydrogel.

Why Natural Polymer Hydrogel and not Another Popular Alternative for Masking Drought Resistance Like Ethanol?

In many pieces of research shown in the past few years, "data observed that application of eco-friendly hydrogel polymers (pectin, starch, and pectin + starch and polymer)... under drought stress conditions… increased leaves chlorophyll and carotenoids values. For reference, carotenoids significantly decrease the chances of diseases in plants. Therefore, this is not only an eco-friendly approach but accredits far more in masking drought resistance in canola crops. Whereas, ethanol sourced from crops like corn has a greater capability to decrease grassy environments, eventually leading to the eroding of soil.

What is the Required Amount of Water for Canola according to Alberta's Government?

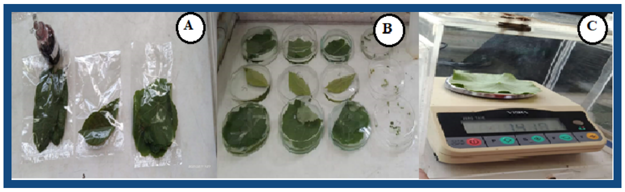
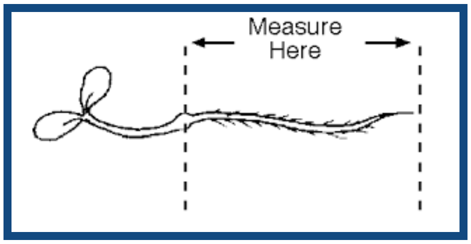
This experiment needs to be as accurate as possible with the drought conditions simulated and the amounts of various materials simultaneously. "For wheat, barley and canola, at least 100 mm (4 inches) and often closer to 125 mm (5 inches) of water are needed daily to get a plant from germination to the reproductive growth stage…" (*Crop Water Use and Requirements*, 2011). This amount translated to 15 canola samplings is 150 mL of water daily which is the required amount.

Adequate pH, EC, and ppm of Irrigation Water for Canola

Name	Measurement	Website/Article
EC	"An EC of 4 is a general salinity rating for traditional annual crops (wheat, canola)..." (*Agriculture* | *Province of Manitoba*, 2016).	"Agriculture | Province of Manitoba." *Province of Manitoba - Agriculture*, 2016, www.gov.mb.ca/agriculture/environment/soil-management/soil-management-guide/soil-salinity.html. Accessed 23 Feb. 2024.
pH	5.5 (slightly acidic)	"Effects of Soil Characteristics | Canola Encyclopedia." *Canola Council of Canada*, 6 May 2022, www.canolacouncil.org/canola-encyclopedia/field-characteristics /effects-of-soil-characteristics/. Accessed 23 Feb. 2024.
ppm	25 ppm (parts-per-million)	Jackson, Grant. "Canola Nutrient Management." *Number*, vol. 22, 1999, agresearch.montana.edu/wtarc/producerinfo/agronomy-nutrient-management/Canola/WTARCCanolaNutMgt.pdf.

What Parameters Will Be Used to Measure Drought Resistance?

Name of Parameter	Brief Description	How Does it Measure Drought Resistance?
Photosynthetic Flotation *(Rate of Photosynthesis)*	"In the leaf-disk assay, all of the components necessary for photosynthesis are present. The light source provides light energy, the solution provides water, and sodium bicarbonate provides dissolved CO_2. Plant material will generally float in water. This is because leaves have air in the spaces between cells, which helps them collect CO_2 gas from their environment to use in photosynthesis. When you apply a gentle vacuum to the leaf disks in solution, this air is forced out and replaced with solution, causing the leaves to sink. When you see tiny bubbles forming on the leaf disks during this experiment, you're observing the net production of O_2 gas as a byproduct of photosynthesis. Accumulation of O_2 on the disks causes them to float. The rate of production of O_2 can be affected by the intensity of the light source, but there is a maximum rate after which more light energy will not increase photosynthesis." (*Photosynthetic Floatation*, 2019)	Photosynthetic flotation is mainly based on the rate of photosynthesis. It is one of the parameters used for measuring drought as "Plant drought tolerance depends on adaptations of the photosynthetic apparatuses…" (Antunović Dunić et al., 2023). The rate of photosynthesis changes in plants when they undergo drought. 

		Photosynthetic Floatation | Exploratorium. (2023, September 29). Exploratorium. https://www.exploratorium.edu/snacks/photosynthetic-floatation
Leaf Relative Water Content (RWC)	"Leaf relative water content (RWC) is an important indicator of water status in plants; it reflects the balance between water supply to the leaf tissue and transpiration rate" (Lugojan and Ciulca 2011).  View. (2021, March 18). *Aim: To measure the relative water content (RWC) in plant tissue*. Plant Science; Plant Science. https://sherubtsebotmal.wordpress.com/2021/03/18/aim-to-measure-the-of-relative-water-content-rwc-in-plant-tissue/	RWC "...represents a composite of the stress severity and the plant response to stress in avoiding water loss and osmotic adjustment to retain water and turgor. RWC measurements can be valuable in experiments as they indicate the extent of dehydration and cellular damage the plant has experienced" (Juenger & Verslues, 2022).
Root Length (cm)	In simple terms, the root length of a plant is the length of the plant's leaves, often measured from the longest root.  *Environmental Inquiry - Lettuce Seed Bioassays*. (2024). Cornell.edu. http://ei.cornell.edu/toxicology/bioassays/lettuce/data.html	*"Root traits such as fine root diameter, specific root length, specific root area, root angle and root length density are useful for improving plant productivity under drought conditions. Roots are the main organs to respond, perceive and maintain crop yield under drought conditions. Plants with deeper root systems extract water from deeper soil layers and help the plants to avoid drought stress"* (Wasaya et al., 2018).
Average Height (cm)	The experiment will be measured by the average height of all the samples in each section and overall height of all the samples.	The height shows the health/productivity under the drought conditions and therefore will be a metric that is an indicator of a plant's drought resistance.

ONE-WORD RESEARCH TO ENSURE THE CANOLA PLANTS' GROWTH IS IN A CONTROLLED ENVIRONMENT

1. **How Long Should Canola Seeds Be Soaked in Water?** - *6-24 hours*
2. **How Long Does it Take for Canola Seeds to Germinate?** - *4-10 days*
3. **What Soil is Best to Grow Canola Plants?** - *Loam soil*

Steps of Photosynthetic Flotation (A.K.A. Floating Leaf Disk Assay) - To Measure Rate of Photosynthesis

1. Prepare the baking soda solution by filling the cup with 300 millilitres (mL) of room-temperature water.
2. Then add about 0.5 g of baking soda to the water and mix until the baking soda has dissolved.
3. Add one drop of dish soap to the baking soda solution and gently stir until it has dissolved. Avoid foam formation in your cup.
4. Set up your light source to shine straight down onto your workspace.
5. With the hole puncher, cut 10 leaf disks from the plant leaves. Make sure they are all the same size and a complete circle. Avoid punching through major leaf veins.
6. Prepare a data table with three columns in your lab notebook. Column 1 is the time, in minutes (min). In column 2 you will record the results of your leaf disk assay—the laboratory procedure you are using to investigate photosynthesis.
7. Remove the plunger from the syringe and place 10 leaf disks into the syringe. Place the plunger back into the syringe and push it down until only a small volume of air is left in the syringe. Be careful not to crush the leaf disks.
8. Suck up a small volume of the baking soda solution into the syringe with the leaf disks. Carefully push all the air out of the syringe.
9. Close the opening of the syringe with a finger and draw back on the plunger to create a vacuum. Hold the vacuum for 10–15 seconds and swirl the leaf disks to suspend them in the solution.
10. Release the plunger and remove your finger from the syringe opening to release the vacuum. Observe the leaf disks. Repeat steps 4 and 5 until all the leaf disks have sunk to the bottom of the solution.
11. Remove the plunger from the syringe and pour all 10 leaf disks and the solution into the cup. Fill the cup with baking soda solution, up to a depth of about 3 cm.

12. Cover the cup with aluminium foil so no light can get in the top. You want to keep the leaf disks in the dark until your other cup is ready.
13. Remove the aluminium foil from the cup and place both cups under your light source. Make sure the light shines straight onto the cups from above.
14. Start a timer. At the end of each minute, record the number of floating leaf disks for both cups in your data table. Briefly swirl the disks to prevent them from getting stuck to the bottom or sides of the cup.
15. Continue the experiment until all leaf disks are floating in one of the cups.
16. Graph your data. Plot the time on the x-axis and the number of floating leaf disks on the y-axis. Record the ET 50 (effective time) of the leaves by noting how much time it takes 50% of the leaves to float to the surface of the cups.

Credit - *Photosynthetic Floatation | Exploratorium. (2023, September 29). Exploratorium. https://www.exploratorium.edu/snacks/photosynthetic-floatation*

Variables that Affect Photosynthetic Flotation *(Part of Variables as well)*

Environmental Variables	*Plant or Leaf Variables*	*Method Variables (These variables may not affect photosynthesis but are still important to investigate)*
○ Light intensity (brightness) Light colour ○ Temperature ○ Bicarbonate concentration (CO2 source) ○ Direction of incoming light pH of solution	○ Leaf colour (chlorophyll amount) ○ Leaf size ○ Stomata density ○ Stomata distribution ○ Light-starved leaves vs. leaves kept in bright light ○ Type of plant ○ Leaf age ○ Leaf variegation ○ Role of respiration in plants along with photosynthesis — measuring gross photosynthesis	○ Size of leaf disk ○ Depth of bicarbonate solution ○ Methods of cutting disks ○ Leaf disk overlap ○ Soap amount ○ How many times can the procedure be repeated with the same disks? How long can the disks remain sunk in the solution — can they be stored overnight? ○ Method of collecting data

Credit - *Big Idea 2 Cellular Processes: Energy and Communication*. (n.d.). https://secure-media.collegeboard.org/digitalServices/pdf/ap/bio-manual/Bio_Lab5-Photosynthesis.pdf

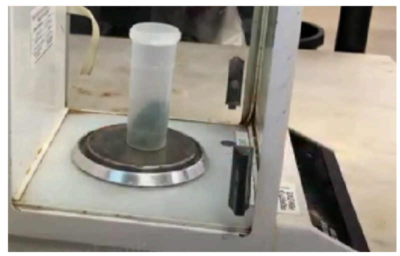
Procedure to Measure R.W.C. (Relative Leaf Water Content)

(According to Method derived from Pennsylvania State University)

Description of Step	*Picture Explaining Step*

1. Punch one leaf disc that is 1 cm wide for one sample of each trial with a single-leaf hole puncher.

2. Store the leaf disc in an airtight container to reduce water loss in the disc. Record the fresh weight of the discs with a milligram scale *(to the nearest milligram)*.



3. Suspend the leaf discs in deionized water (DI water) so they can absorb additional water that they may have expelled through transpiration. Store them in a dark, cool location for 3 hours.

4. After the samples are fully hydrated, decant the leaf discs.

5. Dry the surface of the leaf discs gently with a towel.

6. Weigh the turgid weight of the leaf discs with a milligram scale *(to the nearest milligram)*.

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7. Oven-dry the leaf discs at 80 degrees Celsius for a period of 24 hours.

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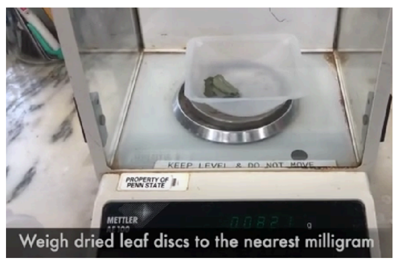
8. Weigh the dried leaf discs to the nearest milligram.



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9. Use the formula for calculating RWC (your answer should be in percent). The higher the R.W.C. the higher the moisture level of the leaf canopy.

Leaf relative water content (RWC) (%):

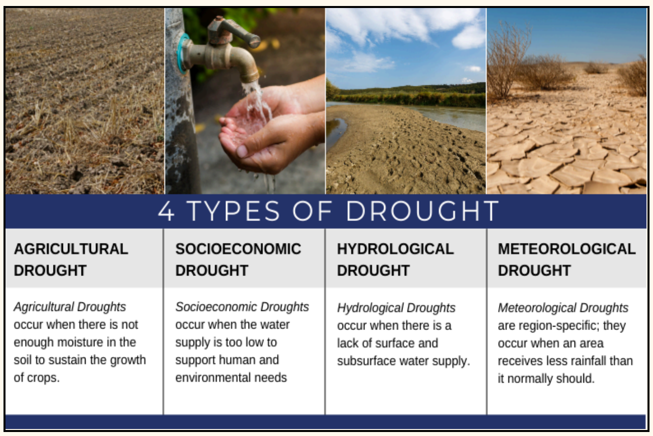
$$RWC(\%) = \left[\frac{(fresh\ weight - dry\ weight)}{(turgid\ weight - dry\ weight)}\right] \times 100$$

Average R.W.C. and Photosynthetic Flotation Rates of Canola

R.W.C.	Photosynthetic Flotation Rate (Effective Time 50)
84.5%–89.6%	7-13 minutes

How is this a Sustainable Approach concerning Alberta's current Agriculture Industry?

"Hydrogels sustain optimum amounts of water in water stress conditions and reabsorb water in moist conditions which ultimately increases seedling, seed germination, plant growth and crop yield. Fertiliser and salt release are majorly dependent upon pH and temperature followed by diffusion-controlled mechanisms" (Azeem, et al.). *"They help the environment through soil management, erosion control and environmental cleanups. The amount of available moisture is increased by the use of hydrogels and water stress of plants which is reduced, causing increased plant performance and growth"* (Walker, et al). Hence, making it not only a feasible option to face drought resistance but also finding the most effective amount can help with future problems with canola and other crops facing drought.



Types of Droughts and Which Type is Being Tested for?

In this experiment, a hydrological drought will be simulated by canola plants not being given water for a total of 8 days. The drought period is not that prolonged due to the canola plants' maturity.

Weatherflow. (2022, September 19). *What is Drought and How to Prepare For It - Tempest Weatherflow*. Tempest.earth; Tempest. https://news.tempest.earth/what-causes-drought

How long does it take for Canola Plants to Dry Out without Hydrogel?

12-15 Days (10 Days of Drought will allow testing for R.W.C. and Photosynthetic Flotation)

Testable Question: Do the Different Amounts of Natural Polymer Hydrogel Enhance Drought-Resistance in Canola Plants?

Hypothesis:

Based on a recent study, "Lignin-based hydrogel alleviates drought stress in maize," it was suggested that hydrogel could be used as a "soil additive to increase water availability to crops experiencing drought stress that will not release undesirable byproducts" (Mazloom et al., 2020). With the current state of canola, especially in Southwestern Alberta, *"Recent… arid conditions in Western Canada have led to catastrophic yield losses of canola…"* (*Generation of Canola Lines with Increased Heat and Drought Tolerance by Regulating Phospholipid: Diacylglycerol Acyltransferase Activity*, n.d.). This is where hydrogel steps to enhance drought resistance since *"hydrogel may prove as a convenient and eco-friendly feasible option to achieve the goal of crop productivity under conditions of water scarcity"* (Yadav & Kumar, 2023). By augmenting the rate of photosynthesis (one of the factors that determines drought resistance) and other metrics e.g. length/number of leaves, average height, R.W.C., and photosynthetic flotation measures drought resistance in a conceptualized idea that they all show a plant's productivity under water stress. The recommended application of hydrogel is 2580mg/1030 cm3 which is my hypothesis as *"for almost all types of crops to soil type and climate of the country, a meagre application rate of hydrogel i.e. 2.5-5.0 Kg/ha is effective"* (Yadav & Kumar, 2023). This is my hypothesis for the most effective amount of hydrogel to ask for drought resistance. In response to these metrics, it is hypothesized that a 2580 mg section/grow tray with the applied hydrogel will have an R.W.C. (leaf relative water content - in %) that will lie in between or be equivalent to the average R.W.C. of canola plants, the average root length will be higher than 5 cm, the average height will be higher than the rest of the samples (estimated < 6), the photosynthetic flotation will lie in between 7-13 minutes (average for canola). Hence, these are the conclusions made to the hypothesized amount of hydrogel that will enhance drought resistance the most: 2580 mg:1030 cubic cm.

Variables:

Independent Variable (Manipulated Variable):

Varying amounts of hydrogel (mg) added in the soil (measured in cm3)

In all sections, the hydrogel was mixed with the first 3 cm of topsoil to ensure the hydrogel reached the roots of the canola plants

RATIO OF HYDROGEL TO SOIL

- SECTION 1: 2580 mg:1030 cm3 with 100 mL of water (Recommended amount)
- SECTION 2: 4000 mg:1030 cm3 with 100 mL of water
- SECTION 3: 1000 mg:1030 cm3 with 100 mL of water
- SECTION 4: Constant section (no hydrogel added/regular growth and drought period)

Responding Variable (Dependent Variable)

Parameters to measure drought resistance:

- Photosynthetic flotation - used to measure the efficacy of hydrogel (Effective Time: "ET_{50}")
- Leaf Relative Water Content (RWC)
- Root length (cm)
- Average leaf count/leaf count of all 24 trials
- Average height of canola plants per section/height of all 24 trials (cm)

Controlled Variable:

- **Temperature:** Around 19°C
- **Canola seeds per section/tray:** 6 (24 IN TOTAL FOR 4 SECTIONS)
- **Type of canola:** Non-GMO, organic, and open-pollinated
- **Quantity of soil per tray (section/grow tray):** 1036 cubic centimetres
- **Number of days for growth period:** 30 days
- **Number of days for drought stimulation period:** 8 days
- **Amount of water for growth period and hydrogel application:** 150 mL
- **Lighting cycle:** 12 hours ON 12 hours OFF
- **Spacing between canola seeds:** 3 inches
- **Type of hydrogel:** super-absorbent, polymer, and natural
- **Number of leaf disks per section for testing photosynthetic flotation:** 10
- **Number of leaf disks per section for testing R.W.C.:** 3
- **Size of the leaf disks:** diameter of 1 cm
- **pH of irrigation water:** 5.5
- **EC of irrigation water:** 4 dS/m
- **ppm of irrigation water:** 25

Materials:

Materials Required for Growing Canola

Granular hydrogel (synthetic polymer-based)
Canola seeds (non-GMO, open-pollinated, and organic) - 24 in total
Water
Grow trays - 1030 cm3 (4)
Standard loam soil
LED lights
Spray Bottle
100-watt light bulb

Measurement tools:

Milligram weight scale
Ruler
Pencil and Notebook
Measuring cup
EC, pH, and ppm testing device

Materials Required to Measure Photosynthetic Flotation:

Needless syringe (20 cc/mL)
Plant discs of the canola leave - 10 leaf discs from each section (40)
Buffer solution: Dish soap + Baking Soda
Water
Timer
Pencil (to record data)
Single-hole puncher (1)
Transparent cups (4)
Measuring cup (max. 500 mL)

Materials Required to Measure Leaf Relative Water Content:

Single-hole puncher
Deionized water (DI water)
Airtight container (4)
Plant discs of the canola leave - 3 leaf discs of each section (12 in total)
Single-hole puncher
Milligram scale
Disposal of drying oven
Pencil to record data

Procedure:

1. For testing, I used non-GMO/organic canola. The "Non-GMO canola seeds are sourced from the colony's farm and from local growers (*Non-GMO, Cold Pressed Canola Oil Brings Self-Sufficiency and International Markets to an Alberta Community*, n.d.)" Helping this make a sustainable approach to drought-resistance in the agriculture of Alberta in numerous ways. They were obtained as seeds and cultivated by the end of a 30-day growth period.

2. Before the growing period, the canola seeds (24 in total) were soaked in 100 mL of water for 12 hours to speed up the germination rate.

3. Meanwhile, I placed 1030 g of soil in 4 grow trays with a volume of 1030 cubic centimetres. I labelled them as, *"SECTION 1: 2580 mg:1030 cm3 with 100 mL of water (Recommended amount), SECTION 2: 4000mg:1030 cm3 with 100 mL of water, SECTION 3: 1000mg:1030 cm3 with 100 mL of water, and SECTION 4: Constant section (no hydrogel added/regular growth and drought period)"* to keep track of which one is which. There is no hydrogel application at the start as it will be applied during the start of the 8-day drought period. I marked the qualitative and quantitative data as well.

4. After the canola seeds were soaked, they were placed in 1030 grams of soil at a distance of 3 inches from one another. and were added to the four growing trays. 6 seeds per tray (4) roughly 3 inches apart. An average temperature of 19℃ was maintained, and seeds were watered daily with 100 mL per tray during the pre-testing growth period of 30 days until plants were approximately three-quarters of the way to maturity. I ensured that the pH of the water was 5.5 (slightly acidic) and EC 4 *(recommended amount)*. The seeds were watered with 400 mL every 4-6 days. The canola seeds experienced a 12-hour lighting cycle with two LED plant lamps (2 trays on each lamp that received roughly the same amount of sunlight).

5. Daily observations and accounting as data, for example, the average height, number of leaves, pigment of leaves, etc. Quantitative (descriptive/in words) and qualitative data (photographs) were taken.

6. After the 30-day growth period of the canola plants, the natural polymer hydrogel treatment was prepared and applied as per the section. The hydrogel is mixed with 3 cm of topsoil and after 100 mL of water scattered across the soil of each tray/section evenly to ensure.

7. Three of the four trays of 24 canola plants were treated with hydrogel except for the constant section. The hydrogel was applied to each tray and 150 mL was added to create the hydrogel.

8. For eight days, the regular watering cycle of all the canola plants was halted to allow the application of solutions. The lighting cycle was not halted as it replicates the presence of sun during a drought.

9. Next, all substances were suspended for 8 days; to simulate drought conditions, the seedlings received only consistent light and temperature conditions. After this, data was recorded (average height, number of leaves, etc).

10. To test the drought resistance of the hydrogels and their efficacy, I used the method of photosynthetic flotation, which measures the rate of photosynthesis of a plant. First, I created 10 leaf discs of each treatment type by punching holes in the leaves of the canola seedlings and inserting them into a needleless syringe. After drawing some buffer solution into the syringe (0.2% baking soda solution with dish soap) a vacuum was applied by plugging the opening with my fingertip and pulling the plunger for 10 seconds. I released the plunger abruptly 2-3 times so that gases could be fully extracted from the leaves. This caused the discs to sink to the bottom of the syringe.

11. Excess air was removed by gently tapping the needless syringe, and the leaf discs were carefully poured into a clear cup of 150 mL of the buffer solution. The cup was placed approximately 20 cm underneath a 100-watt lightbulb and remained there until a minimum of three discs (out of the 10 discs total for each treatment) floated to the solution's surface. Each disc was timed and recorded. This process was repeated four times for each of the sections. The faster they reach the surface, the more efficient the rate of photosynthesis is from quicker oxygen production. This was accounted for as data and recorded.

12. I tested the leaf relative water content to enhance the data by punching five holes in the plants and placing them in an airtight container with the remaining leaves of the canola plants. I took the **fresh weight** of the leaves which was respectively (Sections 1-4) mg to the nearest milligram. I repeated this process four times for each of the sections.

13. Next, I suspended the fresh discs in DI water and stored the containers in a cool, dark place for 3 hours.

14. After the samples are fully hydrated, decant the leaf discs. I gently dried the discs with a paper towel to dry any excess DI water on the surface of the leaves. Then, I weighed the turgid leaf discs to the nearest milligram (3 leaf discs for each section). I oven-dried the leaves in a drying oven for 24 hours at 27°C and weighed them to the nearest milligram (all weights can be seen in calculations and pictures).

15. From this I used the following formula to calculate the RWC (%):

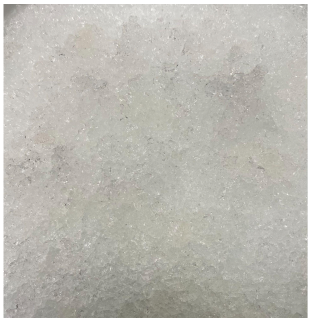
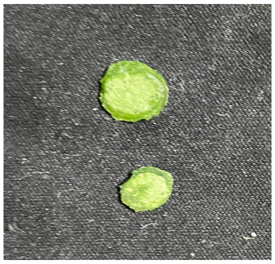
$$(\text{Fresh weight} - \text{Dry weight})/(\text{Turgid weight} - \text{Dry weight}) \times 100$$

16. For the last parameter: root length, I took the canola plants out of the soil, completely measuring each sample's root length and averaged it out. The sections 1-4 root lengths were 13.7 cm, 5.9 cm, 10 cm, and 10.8 cm. I counted it as data.

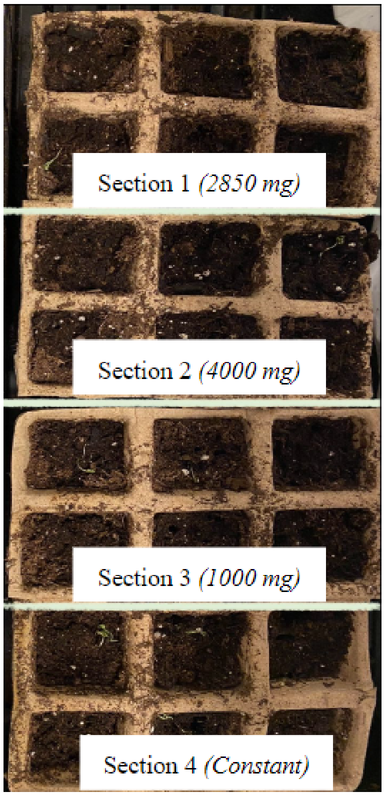
17. I analyzed all the data via the tables, formulas, and some excerpts, and concluded that the recommended amount was the most suitable as per the metrics.

Data Collection (Pictures During the Procedure and Observations):

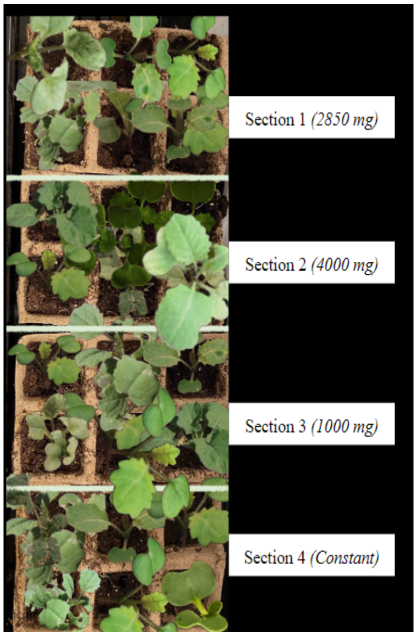
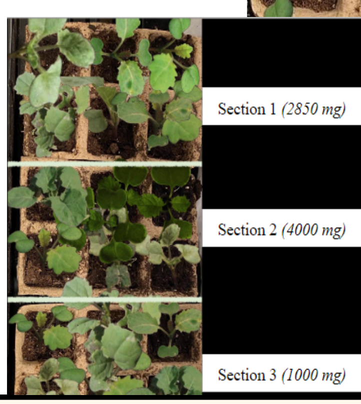
Major Materials Visuals (Personal pictures)

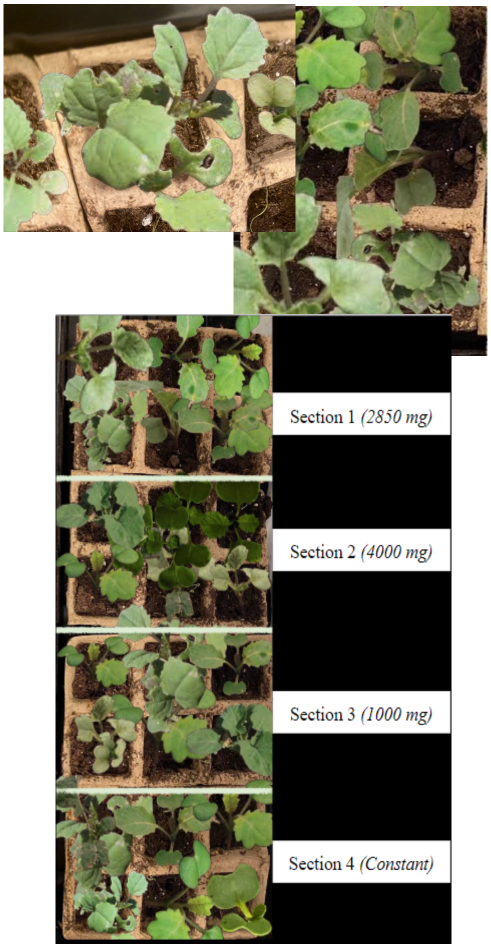
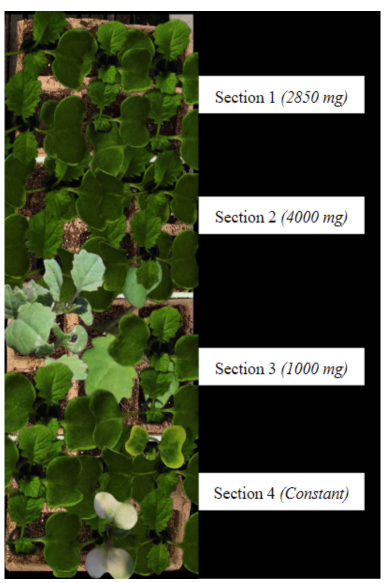
 *Grow trays that were used in the experiment (4 in total)*	 *Loam soil used in the experiment*	 *Non-GMO, organic canola seeds*
 *EC + ppm tester*	 *pH tester*	 *Natural, Polymer Hydrogel*
 *Milligram weight scale*	 *Deionized Water (DI water) - used in R.W.C. testing*	 *Comparison of leaf disc for turgid weight (large) and dry weight (small)*

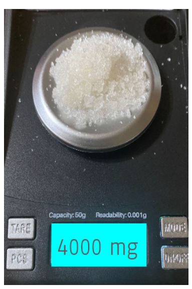
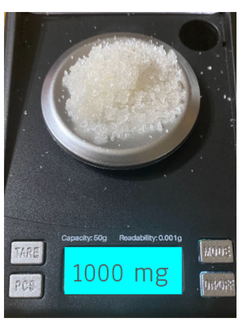
Observations/Data Collection

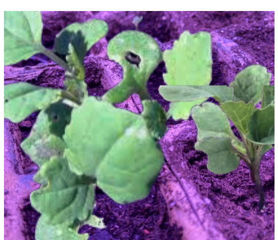
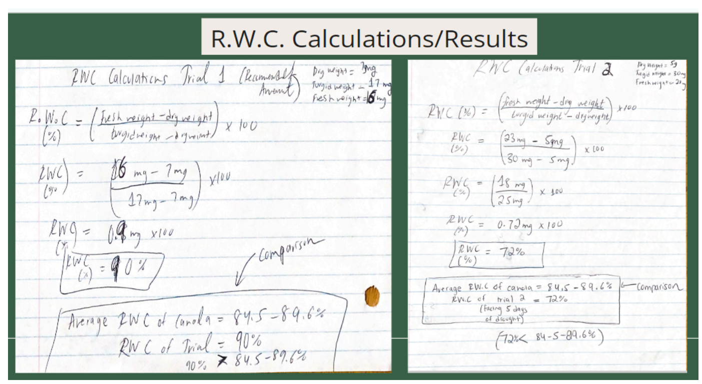
Day #	***Observation during the Respective Day***	
	Qualitative Data (Photographs)	***Qualitative Data (Description of Observations on Respective Day with Average Height - height of all 24 trials can be seen in the quantitative data/logbook/graph page in the lab report and other metrics)***
Germination Period (1 Day)		*The 24 canola non-GMO, organic seeds were soaked for 1 day (24 hours) in water to increase the rate of germination.*
Day 1		***Day 1 of the Growth Period*** ○ Seeds were transplanted 5 mm into the soil ○ There was no growth for all of the samples as it only was the first day of growth. The grow tray sections were divided into sections to keep track of all the samples for the observations ○ In simple terms, no observations could be taken as there was no growth **The average heights of all the sections were recorded (the growth of every single trial can be seen in the Quantitative Data Section which includes the logbooks and Graphs):** **Section 1 *(Recommended)*:** 0 cm **Section 2:** 0 cm **Section 3:** 0 cm **Section 4 *(Constant)***: 0 cm

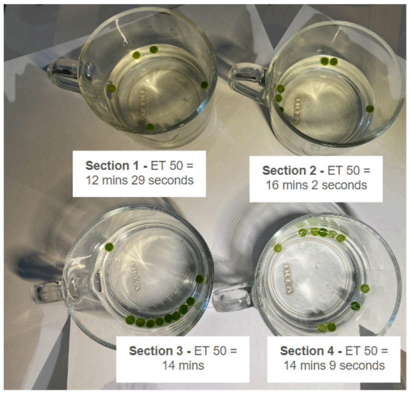
Day 5	  	***Day 5 of the Growth Period:*** ○ Nearly 80% of the samples grew and surprisingly all had around 1-4 leaves (very fast growth) ○ The samples showed exceptional health as evidenced by the dark emerald colour, height of samples (considering it was only the 5th day of growth), and the number of leaves ○ Average leaf count: 3 leaves (1-4) ○ No plants were light green in colour, which was once again a surprise considering it was only the 5th day of the growth period The average heights of all the sections were recorded (individual samples were kept account of - can't be mentioned due to excess samples shown in observations - can be seen in the logbook section with graphs and tables): **Section 1 *(Recommended)*:** 0.3 cm **Section 2:** 0.3 cm **Section 3:** 0.3 cm **Section 4 *(Constant)***: 0.3 cm

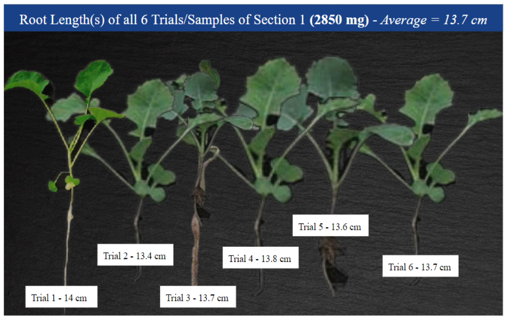
Day 10	 	○ Nearly 95% of the canola samples grew ad were all grass green in pigment with an exception of some being light green ○ As of now, the samples could be said as the same as their stature, leaf count, and pigmentation was pretty similar (can be seen in the picture of the samples above) ○ All sections had pretty similar, which is a good sign as this shows the controlled variables are actually controlled ○ Average leaf count (same as the 5th day - leafs take time to produce): 3 leaves (1-4 leaves) The average heights of all the sections were recorded (individual samples were kept account of - can't be mentioned due to conciseness of information) - can be seen in the Quantitative data with tables and graphs
Day 15	  	○ The average height of all the sample were 6.9 cm, meaning they were pretty healthy for the 15 day growth period ○ The average leaf count of all the samples were 4 leaves, therefore showing sufficient health as per the 15 day growth period ○ The canola plants were growing approximately 0.1-0.9 cm per day as per the current readings

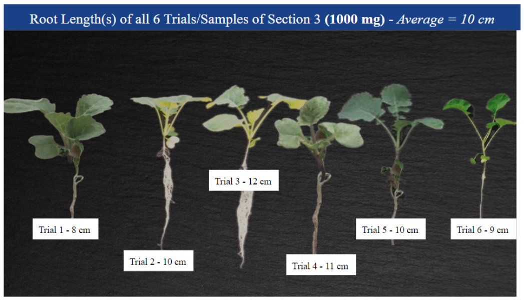
Day 20		○ The average height of all the samples was 7.5 cm, meaning they were pretty healthy for the 20-day growth period ○ The average leaf count of all the samples was 7 leaves (for sections 1-4), therefore showing sufficient health as per the 20 day growth period ○ The canola plants were growing approximately 0.1-1 cm per day as per the current readings ○ Since all the data was controlled/the same for all the sections, I could start the 8-Day Drought Stimulation period, which is a good sign
Day 25		Notable differences could be seen as the pigmentation of the samples overall was getting darker, conveying the health of the canola samples were thriving Height was pretty much same as the 20th day with only some growth Overall, the internodal length increased significantly which showed consistent growth

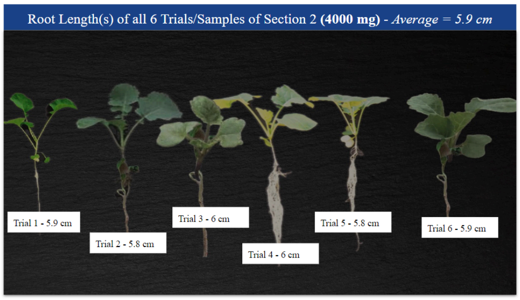
Day 30		**Last Day of Growth Period (30th Day)** ○ No visible changes seen in the overall appearance, height, or pigment of the plants could be detected ○ Average height and leaf count remained the same as 25th (Height increased by 1.3%) No notable difference could be seen in the samples From the background research, it can be inferred that the actual decisive data is the R.W.C. and photosynthetic flotation as it shows the plants condition internally (more in-depth changed in plants' response to water stress/drought)
Day 1	  **Section 1** **Section 2**  **Section 3** **Section 4 (N/A - Constant)** 	**1st Day of Drought Stimulation Period (10 Days) and Hydrogel Application** ○ First all hydrogel amounts were applied to the 3cm of the topsoil of all sections. Below is a visual of the hydrogel and its weight taken by the milligram scale ○ No visible changes seen in the overall appearance, height, or pigment of the plants could be detected ○ Average height and leaf count remained the same as the last day of the growth period No notable difference could be seen in the samples as it is the 1st day of hydrogel application and the drought stimulation period From the background research, it can be inferred that the actual decisive data is the R.W.C. and photosynthetic flotation as it shows the plants condition internally (more in-depth changed in plants' response to water stress/drought)

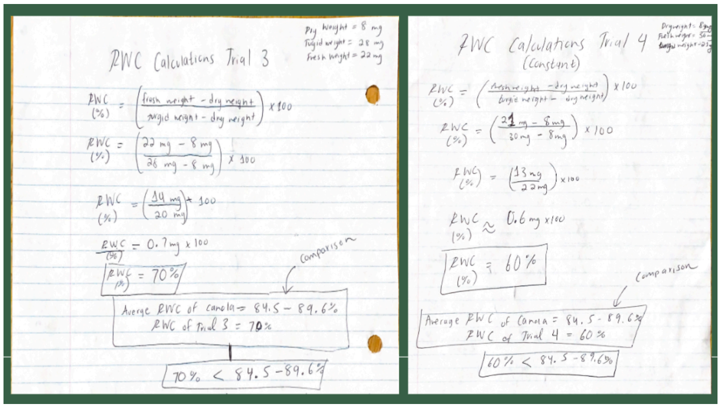
Day 3	  	**3rd Day of Drought Stimulation Period (5 Days) and Hydrogel Application** - No specific observations, but almost all the samplings were showing fairly the same observations as the R.W.C. and photosynthetic flotation would tell what was going on inside of the plants
Day 8	  	- Final observations were taken after the 12-hour lighting cycle and the R.W.C., photosynthetic rates experiments were conducted and the average height, leaf count, pigment, and root length was translated into a statistical analysis below: 











Analysis of all Metrics (Section 1)

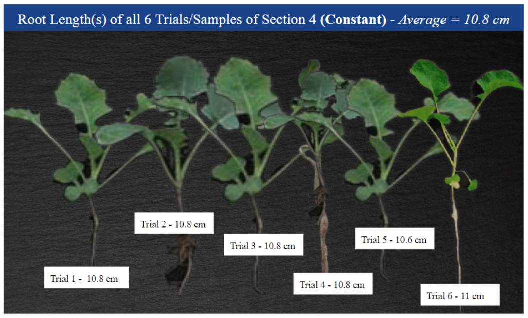
Final average height (cm)	11 cm
Final average leaf count	12
R.W.C. (%)	90%
Photosynthetic Rate (ET 50) - rounded to nearest min.	12 minutes
Final average root length (cm)	13.7

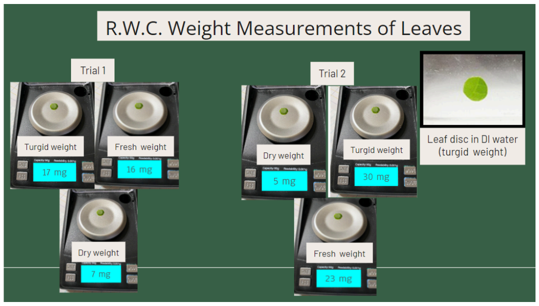
Analysis of all Metrics (Section 2)

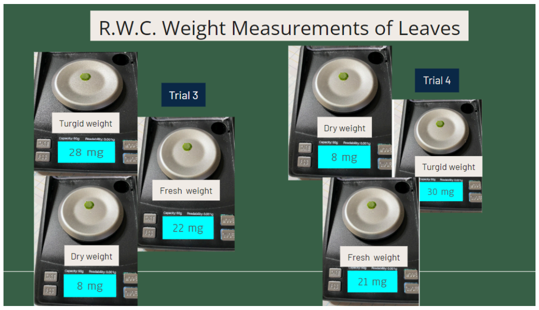
Final average height (cm)	9 cm
Final average leaf count	8
R.W.C. (%)	72%
Photosynthetic Rate (ET 50) - rounded to nearest min.	16 minutes
Final average root length (cm)	5.9

Analysis of all Metrics (Section 3)

Final average height (cm)	9 cm
Final average leaf count	8
R.W.C. (%)	70%
Photosynthetic Rate (ET 50)	14 minutes







- rounded to nearest min.	
Final average root length (cm)	10

Analysis of all Metrics (Section 4)

Final average height (cm)	9 cm
Final average leaf count	9
R.W.C. (%)	60%
Photosynthetic Rate (ET 50) - nearest min.	14 minutes
Final average root length (cm)	10.8

Results: Section 1 was the most effective hydrogel in masking drought resistance in canola plants.

Quantitative Data: Statistical Data and Analysis (Graphs and Table/Logbook)

STATISTICAL ANALYSIS TABLES:-

Irrigation Water Analysis:

Water temperature	19 degrees Celsius
ppm	25 ppm
EC	4 dS/m
pH	5.5 (slightly acidic)

Average Height of all Sections at the end of Growth Period:

Section 1 (Recommended)	9 cm
Section 2	9 cm
Section 3	9 cm
Section 4 (Constant)	9 cm

Average Height Analysis of all Sections After the Drought Period:

Section 1 (Recommended)	11 cm
Section 2	8 cm
Section 3	8 cm
Section 4 (Constant)	9 cm

Average Leaf Count Analysis of all Sections at the End of the Growth Period:

Section 1 (Recommended)	8
Section 2	8
Section 3	8
Section 4 (Constant)	8

R.W.C. and Photosynthetic Flotation - Section 1

ET 50 (Photosynthetic Flotation)	12 min. 26 sec.
R.W.C. (%)	90%

R.W.C. and Photosynthetic Flotation - Section 2

ET 50 (Photosynthetic Flotation)	16 min. 2 sec.
R.W.C. (%)	72%

R.W.C. and Photosynthetic Flotation - Section 3

ET 50 (Photosynthetic Flotation)	14 min.
R.W.C. (%)	70%

R.W.C. and Photosynthetic Flotation - Section 4

ET 50 (Photosynthetic Flotation)	14 min. 9 sec.
R.W.C. (%)	60%

Average Leaf Count of all Sections at the End of the Drought Period:

Section 1 (Recommended)	12
Section 2	8
Section 3	8
Section 4 (Constant)	9

Analysis of all Metrics (Section 1)

Final average height (cm)	11 cm
Final average leaf count	12
R.W.C. (%)	90%
Photosynthetic Rate (ET 50) - rounded to nearest min.	12 minutes
Final average root length (cm)	13.7

Analysis of all Metrics (Section 2)

Final average height (cm)	8 cm
Final average leaf count	8
R.W.C. (%)	72%
Photosynthetic Rate (ET 50) - rounded to nearest min.	16 minutes
Final average root length (cm)	5.9

Analysis of all Metrics (Section 3)

Final average height (cm)	8 cm
Final average leaf count	8
R.W.C. (%)	70%
Photosynthetic Rate (ET 50) - rounded to nearest min.	14 minutes
Final average root length (cm)	10

Analysis of all Metrics (Section 4)

Final average height (cm)	9 cm
Final average leaf count	9
R.W.C. (%)	60%
Photosynthetic Rate (ET 50) - nearest min.	14 minutes
Final average root length (cm)	10.8

Quantitative/Numerical Data: Logbook/Table and Graphs for Data (Average Height - cm, Leaf Count and Others)

Key to Navigate Through Tables/Graphs:

TABLE + GRAPH 1 - #1.1 - 1.4 = Height Data
TABLE + GRAPH 2 - #2.1 - 2.4 = Leaf Count Data
TABLE + GRAPH 3 - #3 = Photosynthetic Flotation Data
TABLE + GRAPH 4 - #4.1 - 4.2 = Root Length Data
TABLE + GRAPH #5 = R.W.C. Data

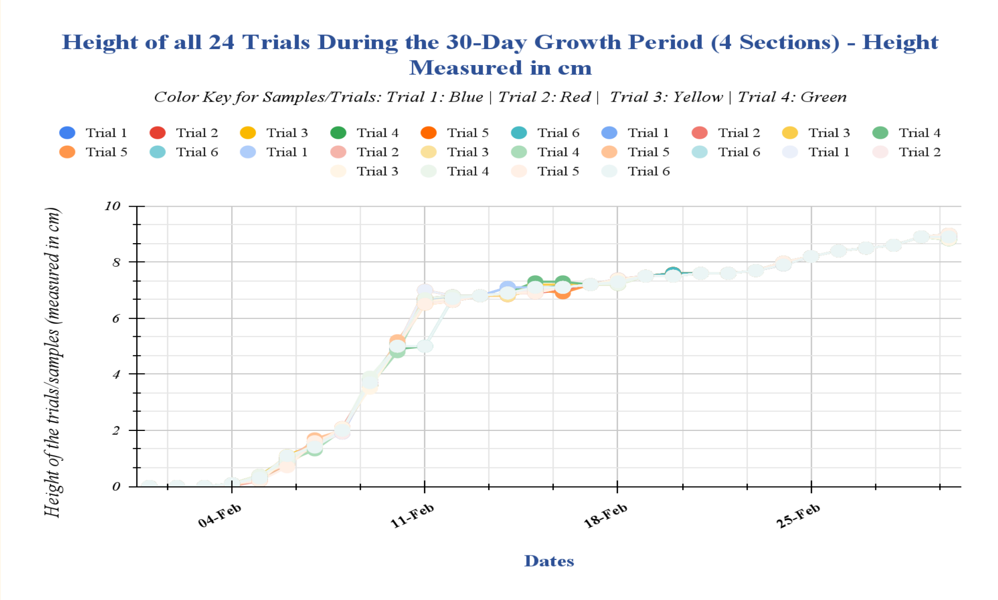
#1.1: Height of all 24 Trials (4 Sections) During the 30-Day Growth Period (4 Sections) - Height in cm

	Section 1: 2580 mg Grow Tray - Heights of Trials/Samples (cm)					
Dates	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**
01-Feb	0	0	0	0	0	0
02-Feb	0	0	0	0	0	0
03-Feb	0	0	0	0	0	0
04-Feb	0	0.1	0.1	0.1	0.1	0.1
05-Feb	0.3	0.3	0.3	0.3	0.2	0.4
06-Feb	1	0.9	1.1	0.9	1	1
07-Feb	1.5	1.5	1.5	1.5	1.5	1.5
08-Feb	2	2	2	2	2	2
09-Feb	3.6	3.7	3.6	3.6	3.6	3.6
10-Feb	5	5	5	5	5	4.9
11-Feb	6.6	6.7	6.7	6.6	6.6	6.6
12-Feb	6.7	6.7	6.7	6.7	6.8	6.6
13-Feb	6.8	6.8	6.8	6.8	6.8	6.8
14-Feb	6.9	6.9	6.9	6.9	6.8	6.9
15-Feb	7	7.1	7	7	7	7
16-Feb	7.1	7.1	7.1	7.1	7	7.2
17-Feb	7.2	7.2	7.2	7.2	7.2	7.2
18-Feb	7.3	7.3	7.3	7.3	7.3	7.2
19-Feb	7.5	7.5	7.5	7.5	7.5	7.5
20-Feb	7.6	7.6	7.6	7.6	7.6	7.6
21-Feb	7.6	7.6	7.6	7.6	7.6	7.6
22-Feb	7.6	7.6	7.6	7.6	7.6	7.6
23-Feb	7.7	7.7	7.7	7.7	7.7	7.7
24-Feb	8	8	8	7.9	8	8
25-Feb	8.2	8.2	8.2	8.2	8.2	8.2
26-Feb	8.4	8.4	8.4	8.4	8.4	8.4
27-Feb	8.5	8.5	8.5	8.5	8.5	8.5
28-Feb	8.6	8.6	8.6	8.6	8.6	8.6
29-Feb	8.9	8.9	8.9	8.9	8.9	8.9
01-Mar	9	8.9	9	8.8	9	9

	Section 2: 4000 mg Grow Tray - Height of Trials/Samples (cm)					
Dates	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**
01-Feb	0	0	0	0	0	0
02-Feb	0	0	0	0	0	0
03-Feb	0	0	0	0	0	0
04-Feb	0.1	0.1	0.1	0.1	0.1	0.1
05-Feb	0.3	0.2	0.4	0.3	0.3	0.3
06-Feb	0.9	0.8	1	0.8	1	1
07-Feb	1.5	1.5	1.4	1.6	1.5	1.5
08-Feb	1.9	2.1	2	2	2	2
09-Feb	3.7	3.7	3.6	3.8	3.6	3.8
10-Feb	5.1	4.9	5	4.9	5	5.1
11-Feb	6.6	6.7	6.5	5	7	6.6
12-Feb	6.7	6.8	6.6	6.7	6.8	6.6
13-Feb	6.8	6.8	6.8	6.8	6.8	6.8
14-Feb	7.1	6.9	6.9	6.9	6.9	6.9
15-Feb	7.1	6.9	7.2	7.3	7	7.1
16-Feb	7.1	7	7.2	7.3	6.9	7.1
17-Feb	7.2	7.2	7.2	7.2	7.2	7.2
18-Feb	7.4	7.4	7.2	7.3	7.3	7.3
19-Feb	7.5	7.5	7.5	7.5	7.5	7.5
20-Feb	7.5	7.5	7.5	7.5	7.5	7.5
21-Feb	7.6	7.6	7.6	7.6	7.6	7.6
22-Feb	7.6	7.6	7.6	7.6	7.6	7.6
23-Feb	7.7	7.7	7.7	7.7	7.7	7.7
24-Feb	8	8	8	8	8	7.9
25-Feb	8.2	8.2	8.2	8.2	8.2	8.2
26-Feb	8.4	8.4	8.4	8.4	8.4	8.4
27-Feb	8.5	8.5	8.5	8.5	8.5	8.5
28-Feb	8.6	8.6	8.6	8.6	8.6	8.6
29-Feb	8.9	8.9	8.9	8.9	8.9	8.9
01-Mar	8.9	9	9	8.8	9	9

	Section 3: 1000 mg Grow Tray - Height of Trials/Samples (cm)					
Dates	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**
01-Feb	0	0	0	0	0	0
02-Feb	0	0	0	0	0	0
03-Feb	0	0	0	0	0	0
04-Feb	0.1	0	0.1	0.1	0	0.1
05-Feb	0.3	0.2	0.4	0.3	0.3	0.3
06-Feb	0.9	1	0.8	0.9	0.8	1
07-Feb	1.5	1.6	1.4	1.3	1.7	1.5
08-Feb	2	2	2	2	2	2
09-Feb	3.7	3.6	3.6	3.6	3.6	3.6
10-Feb	4.9	5	5.1	4.8	5.2	5
11-Feb	6.6	6.6	6.6	6.7	6.5	5
12-Feb	6.8	6.6	6.7	6.8	6.6	6.7
13-Feb	6.8	6.8	6.8	6.8	6.8	6.8
14-Feb	7.1	6.9	6.8	6.9	6.9	6.9
15-Feb	7.1	6.9	7	7	7	7
16-Feb	7.1	7.1	7.1	7.1	7.1	7.1
17-Feb	7.2	7.2	7.2	7.2	7.2	7.2
18-Feb	7.3	7.3	7.3	7.3	7.3	7.3
19-Feb	7.5	7.5	7.5	7.5	7.5	7.5
20-Feb	7.5	7.5	7.5	7.5	7.5	7.5
21-Feb	7.6	7.6	7.6	7.6	7.6	7.6
22-Feb	7.6	7.6	7.6	7.6	7.6	7.6
23-Feb	7.7	7.7	7.7	7.7	7.7	7.7
24-Feb	7.9	7.9	8	8	8	8
25-Feb	8.2	8.2	8.2	8.2	8.2	8.2
26-Feb	8.4	8.4	8.4	8.4	8.4	8.4
27-Feb	8.5	8.5	8.5	8.5	8.5	8.5
28-Feb	8.6	8.6	8.6	8.6	8.6	8.6
29-Feb	8.9	8.9	8.9	8.9	8.9	8.9
01-Mar	9	8.9	9	8.8	9	9

	Section 4: Constant Grow Tray - Height of Trials/Samples (cm)					
Dates	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**
01-Feb	0	0	0	0	0	0
02-Feb	0	0	0	0	0	0
03-Feb	0	0	0	0	0	0
04-Feb	0.1	0	0.1	0.1	0.1	0.1
05-Feb	0.3	0.4	0.2	0.4	0.2	0.3
06-Feb	0.9	0.8	1	0.9	0.7	1.1
07-Feb	1.5	1.5	1.5	1.5	1.6	1.4
08-Feb	2	1.9	2.1	2	2	2
09-Feb	3.6	3.8	3.5	3.9	3.7	3.7
10-Feb	5	5	5	5	5	5
11-Feb	7	6.6	6.6	6.7	6.5	5
12-Feb	6.8	6.6	6.7	6.8	6.6	6.7
13-Feb	6.8	6.8	6.8	6.8	6.8	6.8
14-Feb	6.9	6.9	6.9	6.9	6.9	6.9
15-Feb	7	7	6.9	7.1	6.9	7.1
16-Feb	7.1	7.1	7.1	7.1	7.1	7.1
17-Feb	7.2	7.2	7.2	7.2	7.2	7.2
18-Feb	7.3	7.3	7.4	7.2	7.3	7.3
19-Feb	7.5	7.5	7.5	7.5	7.5	7.5
20-Feb	7.5	7.5	7.5	7.5	7.5	7.5
21-Feb	7.6	7.6	7.6	7.6	7.6	7.6
22-Feb	7.6	7.6	7.6	7.6	7.6	7.6
23-Feb	7.7	7.7	7.7	7.7	7.7	7.7
24-Feb	8	8	8	8	8	7.9
25-Feb	8.2	8.2	8.2	8.2	8.2	8.2
26-Feb	8.4	8.4	8.4	8.4	8.4	8.4
27-Feb	8.5	8.5	8.5	8.5	8.5	8.5
28-Feb	8.6	8.6	8.6	8.6	8.6	8.6
29-Feb	8.9	8.9	8.9	8.9	8.9	8.9
01-Mar	9	9	8.8	9	9	8.9



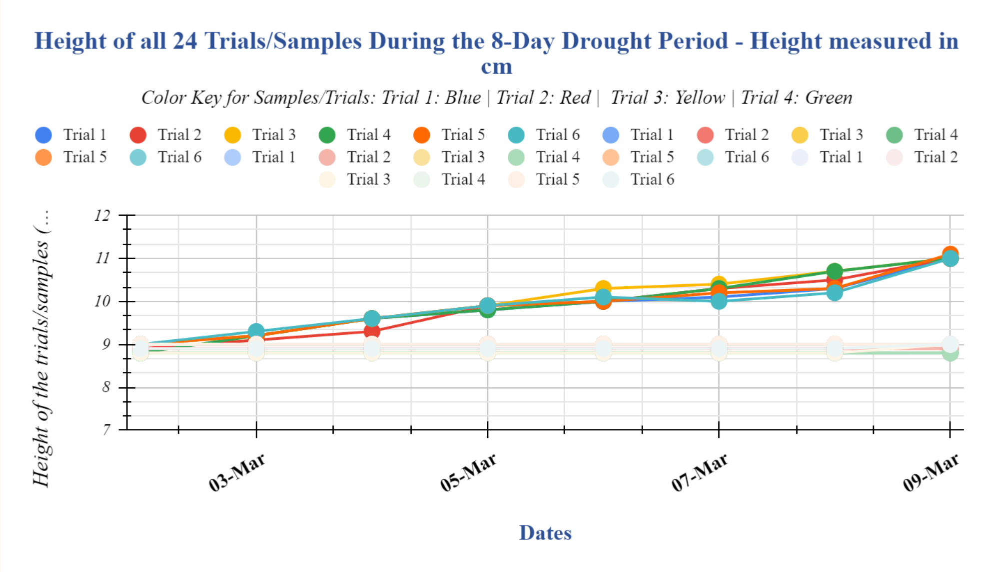
#1.2: Height of all 24 Trials (4 Sections) During the 8-Day Drought Period (4 Sections) - Height in cm

	Section 1: 2580 mg Grow Tray - Heights of Trials/Samples (cm)					
Dates	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
02-Mar	9	8.9	9	8.8	9	9
03-Mar	9.2	9.1	9.2	9.2	9.2	9.3
04-Mar	9.6	9.3	9.6	9.6	9.6	9.6
05-Mar	9.8	9.9	9.9	9.8	9.9	9.9
06-Mar	10	10	10.3	10	10	10.1
07-Mar	10.1	10.3	10.4	10.3	10.2	10
08-Mar	10.3	10.5	10.7	10.7	10.3	10.2
09-Mar	11	11	11	11	11.1	11

	Section 2: 4000 mg Grow Tray - Height of Trials/Samples (cm)					
Dates	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
02-Mar	9	8.9	9	8.8	9	9
03-Mar	9	8.9	9	8.8	9	9
04-Mar	9	8.9	9	8.8	9	9
05-Mar	9	8.9	9	8.8	9	9
06-Mar	9	8.9	9	8.8	9	9
07-Mar	9	8.9	9	8.8	9	9
08-Mar	9	8.9	9	8.8	9	9
09-Mar	9	8.9	9	8.8	9	9

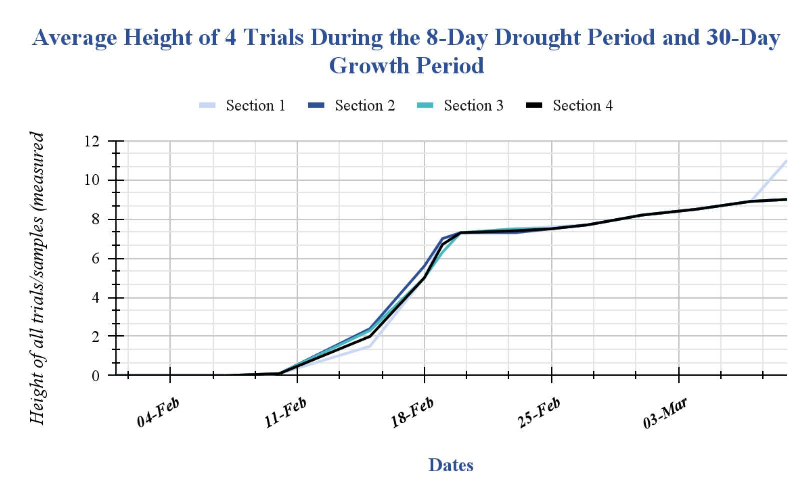
	Section 3: 1000 mg Grow Tray - Height of Trials/Samples (cm)					
Dates	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
02-Mar	9	8.9	9	8.8	9	9
03-Mar	9	8.9	9	8.8	9	9
04-Mar	9	8.9	9	8.8	9	9
05-Mar	9	8.9	9	8.8	9	9
06-Mar	9	8.9	9	8.8	9	9
07-Mar	9	8.9	9	8.8	9	9
08-Mar	9	8.9	9	8.8	9	9
09-Mar	9	8.9	9	8.8	9	9

	Section 4: Constant Grow Tray - Heights of Trials/Samples (cm)					
Dates	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
02-Mar	9	9	8.8	9	9	8.9
03-Mar	9	9	8.8	9	9	8.9
04-Mar	9	9	8.8	9	9	8.9
05-Mar	9	9	8.8	9	9	8.9
06-Mar	9	9	8.8	9	9	8.9
07-Mar	9	9	8.8	9	9	8.9
08-Mar	9	9	8.8	9	9	8.9
09-Mar	9	9	9	9	9	9



#1.3: Average Height of 24 Trials (4 Sections) During the 30-Day Growth Period and 8-Day Drought Period - Height in cm

	Average Height of all Sections (24 Trials) - Height measured in cm			
Dates	**Section 1**	**Section 2**	**Section 3**	**Section 4**
01-Feb	0	0	0	0
03-Feb	0	0	0	0
04-Feb	0.1	0.1	0.1	0.1
07-Feb	1.5	2.4	2.3	2
10-Feb	5	5.6	5	5
15-Feb	7	7	6.3	6.7
18-Feb	7.3	7.3	7.3	7.3
19-Feb	7.5	7.3	7.5	7.4
20-Feb	7.6	7.5	7.5	7.5
23-Feb	7.7	7.7	7.7	7.7
25-Feb	8.2	8.2	8.2	8.2
27-Feb	8.5	8.5	8.5	8.5
01-Mar	8.9	8.9	8.9	8.9
04-Mar	9.6	9	9	8.9
09-Mar	11	9	9	9



#1.4: E.E.I. (Extended Experimental Investigation) - Statistical Data for Height During the 30-Day Growth Period and 8-Day Drought Stimulation Period (4 Sections)

	Section 1: 2580 mg Grow Tray - Heights of Trials/Samples (cm)								
Dates	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Average**	**Change in Length**	**% Change in Length**
01-Feb	0	0	0	0	0	0	0	0	0%
03-Feb	0	0	0	0	0	0	0	0	0%
04-Feb	0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0%
07-Feb	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.4	7%
10-Feb	5	5	5	5	5	4.9	5	3.5	43%
15-Feb	7	7.1	7	7	7	7	7	2	40%
18-Feb	7.3	7.3	7.3	7.3	7.3	7.2	7.3	0.3	4%
19-Feb	7.5	7.5	7.5	7.5	7.5	7.5	7.5	0.2	3%
20-Feb	7.6	7.6	7.6	7.6	7.6	7.6	7.6	0.1	1%
23-Feb	7.7	7.7	7.7	7.7	7.7	7.7	7.7	0.1	1%
25-Feb	8.2	8.2	8.2	8.2	8.2	8.2	8.2	0.5	6%
27-Feb	8.5	8.5	8.5	8.5	8.5	8.5	8.5	0.3	4%
01-Mar	9	8.9	9	8.8	9	9	8.9	0.4	5%
04-Mar	9.6	9.3	9.6	9.6	9.6	9.6	9.6	0.4	4%
09-Mar	11	11	11	11	11.1	11	11	10.7	90%

	Section 2: 4000 mg Grow Tray - Height of Trials/Samples (cm)								
Dates	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Average**	**Change in Length**	**% Change in Length**
01-Feb	0	0	0	0	0	0	0	0	0%
03-Feb	0	0	0	0	0	0	0	0.1	0%
04-Feb	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0%
07-Feb	1.5	1.5	1.4	1.6	1.5	1.5	1.5	1.4	7%
10-Feb	5.1	4.9	5	4.9	5	5.1	5	3.5	43%
15-Feb	7.1	6.9	7.2	7.3	7	7.1	7.1	2.1	42%
18-Feb	7.4	7.4	7.2	7.3	7.3	7.3	7.3	0.2	3%
19-Feb	7.5	7.5	7.5	7.5	7.5	7.5	7.5	0.2	3%
20-Feb	7.5	7.5	7.5	7.5	7.5	7.5	7.5	0	0%
23-Feb	7.7	7.7	7.7	7.7	7.7	7.7	7.7	0.2	3%
25-Feb	8.2	8.2	8.2	8.2	8.2	8.2	8.2	0.5	6%
27-Feb	8.5	8.5	8.5	8.5	8.5	8.5	8.5	0.3	4%
01-Mar	8.9	9	9	8.8	9	9	8.9	0.45	5%
04-Mar	9	8.9	9	8.8	9	9	9	0.1	10%
09-Mar	9	8.9	9	8.8	9	9	9	0	0%

	Section 3: 1000 mg Grow Tray - Height of Trials/Samples (cm)								
Dates	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Average**	**Change in Length**	**% Change in Length**
01-Feb	0	0	0	0	0	0	0	0	0%
03-Feb	0	0	0	0	0	0	0	0	0%
04-Feb	0.1	0	0.1	0.1	0	0.1	0.1	0.1	0%
07-Feb	1.5	1.6	1.4	1.3	1.7	1.5	1.5	1.4	7%
10-Feb	4.9	5	5.1	4.8	5.2	5	5	3.5	43%
15-Feb	7.1	6.9	7	7	7	7	7	2	40%
18-Feb	7.3	7.3	7.3	7.3	7.3	7.3	7.3	0.3	4%
19-Feb	7.5	7.5	7.5	7.5	7.5	7.5	7.5	0.2	3%
20-Feb	7.5	7.5	7.5	7.5	7.5	7.5	7.5	0	0%
23-Feb	7.7	7.7	7.7	7.7	7.7	7.7	7.7	0.2	3%
25-Feb	8.2	8.2	8.2	8.2	8.2	8.2	8.2	0.5	6%
27-Feb	8.5	8.5	8.5	8.5	8.5	8.5	8.5	0.3	4%
01-Mar	9	8.9	9	8.8	9	9	8.9	0.5	6%
04-Mar	9	8.9	9	8.8	9	9	9	0.1	1%
09-Mar	9	8.9	9	8.8	9	9	9	0.1	1%

	Section 4: Constant Grow Tray - Height of Trials/Samples (cm)								
Dates	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Average**	**Change in Length**	**% Change in Length**
01-Feb	0	0	0	0	0	0	0	0	0%
03-Feb	0	0	0	0	0	0	0	0.1	0%
04-Feb	0.1	0	0.1	0.1	0.1	0.1	0.1	1.4	0%
07-Feb	1.5	1.5	1.5	1.5	1.6	1.4	1.5	1.4	14%
10-Feb	5	5	5	5	5	5	5	3.5	35%
15-Feb	7	7	6.9	7.1	6.9	7.1	7	2	40%
18-Feb	7.3	7.3	7.4	7.2	7.3	7.3	7.3	0.3	4%
19-Feb	7.5	7.5	7.5	7.5	7.5	7.5	7.5	0.2	3%
20-Feb	7.5	7.5	7.5	7.5	7.5	7.5	7.5	0	0%
23-Feb	7.7	7.7	7.7	7.7	7.7	7.7	7.7	0.2	3%
25-Feb	8.2	8.2	8.2	8.2	8.2	8.2	8.2	0.5	6%
27-Feb	8.5	8.5	8.5	8.5	8.5	8.5	8.5	0.3	4%
01-Mar	9	9	8.8	9	9	8.9	8.9	0.4	5%
04-Mar	9	9	8.8	9	9	8.9	8.9	0	0%
09-Mar	9	9	9	9	9	9	9	0.1	1%

#2.1: Leaf Count of all 24 Trials (4 Sections) During the 30-Day Growth Period (4 Sections) - Height in cm

	Section 1: 2580 mg Grow Tray - Leaf Count					
Dates	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
01-Feb	0	0	0	0	0	0
02-Feb	0	0	0	0	0	0
03-Feb	0	0	0	0	0	0
04-Feb	1	1	1	1	1	1
05-Feb	1	1	1	2	1	1
06-Feb	2	2	2	2	2	2
07-Feb	2	2	2	2	2	2
08-Feb	2	2	2	2	2	2
09-Feb	2	2	2	2	2	2
10-Feb	2	3	3	3	2	3
11-Feb	2	3	3	3	2	3
12-Feb	3	3	3	3	3	3
13-Feb	4	4	4	4	4	4
14-Feb	4	4	4	4	4	4
15-Feb	4	4	4	4	4	4
16-Feb	6	6	5	5	6	6
17-Feb	6	6	6	6	6	6
18-Feb	7	7	7	7	7	7
19-Feb	7	7	7	7	7	7
20-Feb	7	7	7	7	7	7
21-Feb	7	7	7	7	7	7
22-Feb	8	7	7	8	8	7
23-Feb	8	7	7	8	8	8
24-Feb	8	7	7	8	8	8
25-Feb	8	7	7	8	8	8
26-Feb	8	7	7	8	8	8
27-Feb	8	7	7	8	8	8
28-Feb	8	7	7	8	8	8
29-Feb	8	7	7	8	8	8
01-Mar	8	7	7	8	8	8

	Section 2: 4000 mg Grow Tray - Leaf Count					
Dates	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
01-Feb	0	0	0	0	0	0
02-Feb	0	0	0	0	0	0
03-Feb	0	0	0	0	0	0
04-Feb	1	1	1	1	1	1
05-Feb	1	2	1	1	1	2
06-Feb	2	2	2	2	2	2
07-Feb	2	2	2	2	2	2
08-Feb	2	2	2	2	2	2
09-Feb	2	2	2	2	2	2
10-Feb	3	3	2	3	3	3
11-Feb	3	3	2	3	3	3
12-Feb	3	3	3	3	3	3
13-Feb	4	4	4	4	4	4
14-Feb	4	4	4	4	4	4
15-Feb	4	4	4	4	4	4
16-Feb	5	5	6	6	5	5
17-Feb	6	6	6	6	6	6
18-Feb	7	7	7	7	7	7
19-Feb	7	7	7	7	7	7
20-Feb	7	7	7	7	7	7
21-Feb	7	7	7	7	7	7
22-Feb	7	8	7	7	7	7
23-Feb	7	8	7	7	7	7
24-Feb	7	8	7	7	7	7
25-Feb	7	8	7	7	7	7
26-Feb	7	8	7	7	7	7
27-Feb	7	8	7	7	8	7
28-Feb	7	8	7	7	8	7
29-Feb	7	8	7	7	8	8
01-Mar	7	8	7	7	8	8

	Section 3: 1000 mg Grow Tray - Leaf Count					
Dates	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
01-Feb	0	0	0	0	0	0
02-Feb	0	0	0	0	0	0
03-Feb	0	0	0	0	0	0
04-Feb	1	1	1	1	1	1
05-Feb	1	2	1	1	1	2
06-Feb	2	2	2	2	2	2
07-Feb	2	2	2	2	2	2
08-Feb	2	2	2	2	2	2
09-Feb	2	2	2	2	2	2
10-Feb	3	3	2	3	3	3
11-Feb	3	3	2	3	3	3
12-Feb	3	3	3	3	3	3
13-Feb	4	4	4	4	4	4
14-Feb	4	4	4	4	4	4
15-Feb	4	4	4	4	4	4
16-Feb	5	5	6	6	5	5
17-Feb	6	6	6	6	6	6
18-Feb	7	7	7	7	7	7
19-Feb	7	7	7	7	7	7
20-Feb	7	7	7	7	7	7
21-Feb	7	7	7	7	7	7
22-Feb	7	8	7	7	7	7
23-Feb	7	8	7	7	7	7
24-Feb	7	8	7	7	7	7
25-Feb	7	8	7	7	7	7
26-Feb	8	8	8	8	8	8
27-Feb	8	8	8	8	8	8
28-Feb	8	8	8	8	8	8
29-Feb	8	8	8	8	8	8
01-Mar	8	8	8	8	8	8

	Section 4: Constant Grow Tray - Leaf Count					
Dates	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
01-Feb	0	0	0	0	0	0
02-Feb	0	0	0	0	0	0
03-Feb	0	0	0	0	0	0
04-Feb	1	1	1	1	1	1
05-Feb	1	2	1	1	1	2
06-Feb	2	2	2	2	2	2
07-Feb	2	2	2	2	2	2
08-Feb	2	2	2	2	2	2
09-Feb	2	2	2	2	2	2
10-Feb	3	3	2	3	3	3
11-Feb	3	3	2	3	3	3
12-Feb	3	3	3	3	3	3
13-Feb	4	4	4	4	4	4
14-Feb	4	4	4	4	4	4
15-Feb	4	4	4	4	4	4
16-Feb	5	5	6	6	5	5
17-Feb	6	6	6	6	6	6
18-Feb	7	7	7	7	7	7
19-Feb	7	7	7	7	7	7
20-Feb	7	7	7	7	7	7
21-Feb	7	7	7	7	7	7
22-Feb	7	8	8	7	7	8
23-Feb	7	8	8	7	7	8
24-Feb	7	8	8	7	7	8
25-Feb	7	8	8	8	7	8
26-Feb	7	8	8	8	8	8
27-Feb	7	8	8	8	8	8
28-Feb	8	8	8	8	8	8
29-Feb	8	8	8	8	8	8
01-Mar	8	8	8	8	8	8

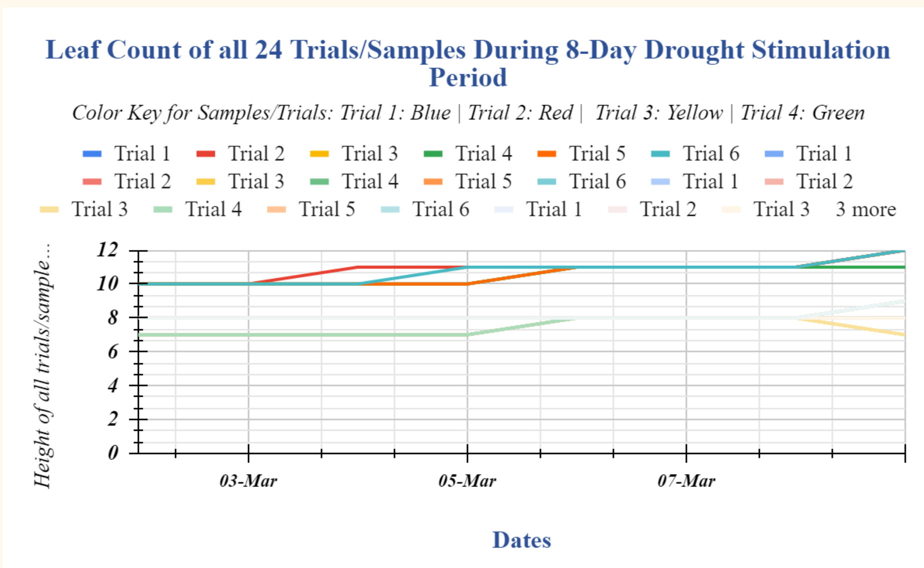
#2.2: Leaf Count of all 24 Trials (4 Sections) During the 8-Day Drought Period (4 Sections) - Height in cm

	Section 1: 2580 mg Grow Tray - Heights of Trials/Samples (cm)					
Dates	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**
02-Mar	10	10	10	10	10	10
03-Mar	10	10	10	10	10	10
04-Mar	10	11	10	10	10	10
05-Mar	10	11	10	10	10	11
06-Mar	11	11	11	11	11	11
07-Mar	11	11	11	11	11	11
08-Mar	11	11	11	11	11	11
09-Mar	12	12	11	11	12	12

	Section 2: 4000 mg Grow Tray - Height of Trials/Samples (cm)					
Dates	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**
02-Mar	7	8	7	7	8	8
03-Mar	7	8	7	7	8	8
04-Mar	7	8	7	7	8	8
05-Mar	7	8	7	7	8	8
06-Mar	8	8	8	8	8	8
07-Mar	8	8	8	8	8	8
08-Mar	8	8	8	8	8	8
09-Mar	8	8	7	9	8	8

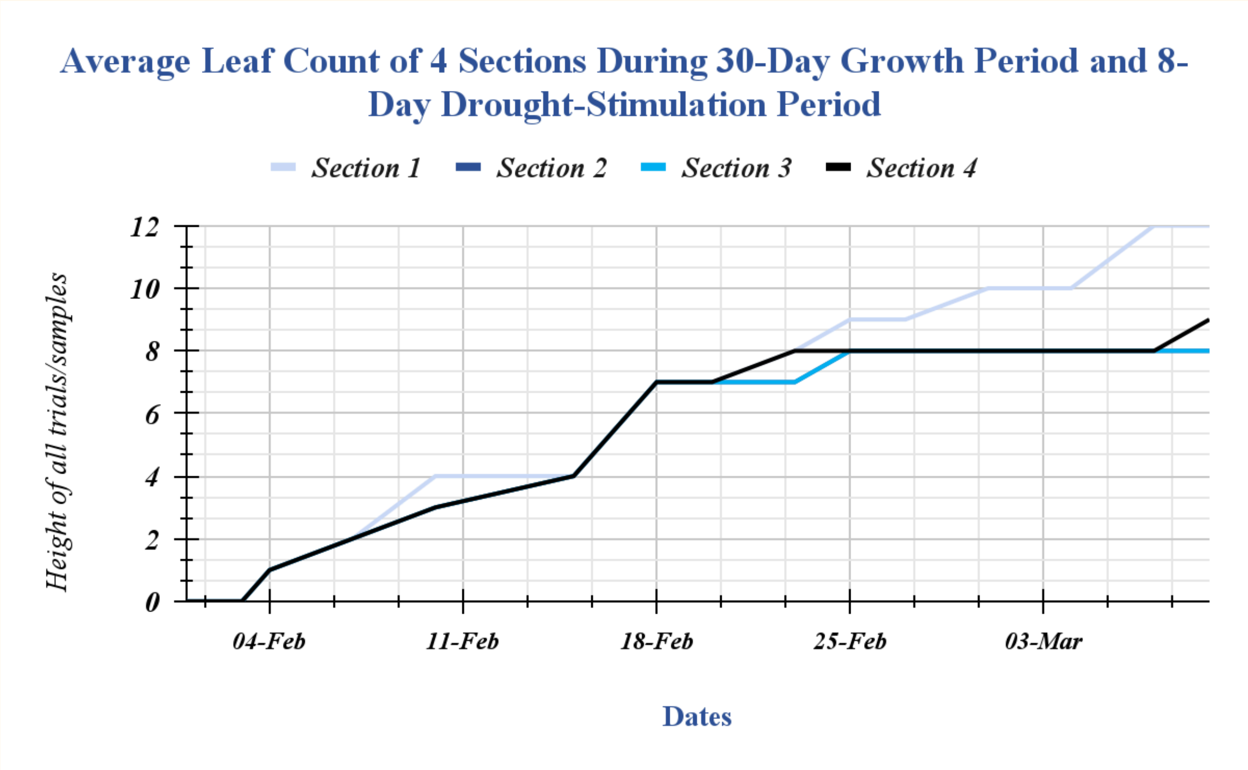
	Section 3: 1000 mg Grow Tray - Height of Trials/Samples (cm)					
Dates	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**
02-Mar	7	8	7	7	8	8
03-Mar	7	8	7	7	8	8
04-Mar	7	8	7	7	8	8
05-Mar	7	8	7	7	8	8
06-Mar	8	8	8	8	8	8
07-Mar	8	8	8	8	8	8
08-Mar	8	8	8	8	8	8
09-Mar	8	8	7	9	8	8

	Section 4: Constant Grow Tray - Heights of Trials/Samples (cm)					
Dates	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**
02-Mar	8	8	8	8	8	8
03-Mar	8	8	8	8	8	8
04-Mar	8	8	8	8	8	8
05-Mar	8	8	8	8	8	8
06-Mar	8	8	8	8	8	8
07-Mar	8	8	8	8	8	8
08-Mar	8	8	8	8	8	8
09-Mar	8	8	8	9	9	9



#2.3: Average Leaf Count of 4 Sections During the 30-Day Growth Period and 8-Day Drought Period - Height in cm

Average Leaf Count of all Sections (24 Trials) - Height measured in cm				
Dates	**Section 1**	**Section 2**	**Section 3**	**Section 4**
01-Feb	0	0	0	0
03-Feb	0	0	0	0
04-Feb	1	1	1	1
07-Feb	2	2	2	2
10-Feb	4	3	3	3
15-Feb	4	4	4	4
18-Feb	7	7	7	7
19-Feb	7	7	7	7
20-Feb	7	7	7	7
23-Feb	8	7	7	8
25-Feb	9	8	8	8
27-Feb	9	8	8	8
01-Mar	10	8	8	8
04-Mar	10	8	8	8
07-Mar	12	8	8	8
09-March	12	8	8	9



#2.4: E.E.I. (Extended Experimental Investigation) - Statistical Data for Leaf Count During the 30-Day Growth Period and 8-Day Drought Stimulation Period (4 Sections)

	Section 1: 2580 mg Grow Tray - Heights of Trials/Samples (cm)								
Dates	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Average**	**Change in Length**	**% Change in Length**
01-Feb	0	0	0	0	0	0	0	0	0%
03-Feb	0	0	0	0	0	0	0	0	0%
04-Feb	1	1	1	1	1	1	1	1	0%
07-Feb	2	2	2	2	2	2	2	1	0%
10-Feb	2	3	3	3	2	3	3.5	1.5	75%
15-Feb	4	4	4	4	4	4	4	0.5	14%
18-Feb	7	7	7	7	7	7	7	3	75%
19-Feb	7	7	7	7	7	7	7	0	0%
20-Feb	7	7	7	7	7	7	7	0	0%
23-Feb	8	7	7	7	8	8	8	1	14%
25-Feb	9	10	9	8	9	9	9	1	13%
27-Feb	9	10	9	8	9	9	9	0	0%
01-Mar	10	10	10	10	10	10	10	1	11%
04-Mar	10	11	10	10	10	10	10	2	20%
09-Mar	12	12	11	11	12	12	12	2	20%

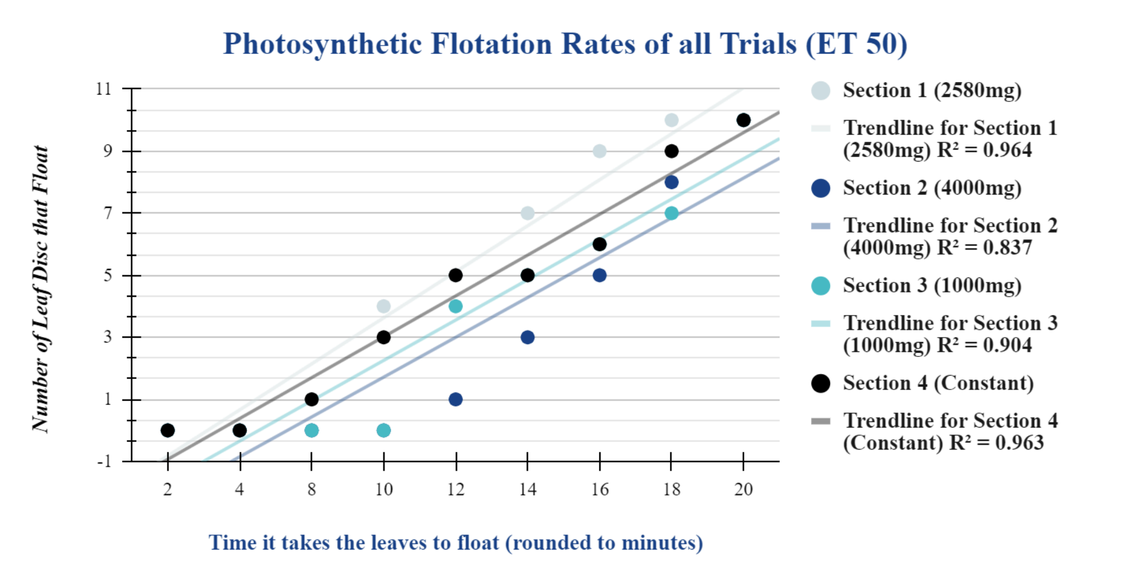
	Section 2: 4000 mg Grow Tray - Height of Trials/Samples (cm)								
Dates	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Average**	**Change in Length**	**% Change in Length**
01-Feb	0	0	0	0	0	0	0	0	0%
03-Feb	0	0	0	0	0	0	0	0	0%
04-Feb	1	1	1	1	1	1	1	1	0%
07-Feb	2	2	2	2	2	2	2	1	0%
10-Feb	3	3	2	3	3	3	3	1	0%
15-Feb	4	4	4	4	4	4	4	1	0%
18-Feb	7	7	7	7	7	7	7	3	75%
19-Feb	7	7	7	7	7	7	7	0	0%
20-Feb	7	7	7	7	7	7	7	0	0%
23-Feb	7	8	7	7	7	7	7	0	0%
25-Feb	7	8	7	7	8	8	8	1	14%
27-Feb	7	8	7	7	8	7	8	0	0%
01-Mar	7	8	7	7	8	8	8	0	0%
04-Mar	7	8	7	7	8	7	8	0	0%
09-Mar	7	8	7	7	8	8	8	0	0%

	Section 3: 1000 mg Grow Tray - Height of Trials/Samples (cm)								
Dates	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Average**	**Change in Length**	**% Change in Length**
01-Feb	0	0	0	0	0	0	0	0	0%
03-Feb	0	0	0	0	0	0	0	0	0%
04-Feb	1	1	1	1	1	1	1	1	0%
07-Feb	2	2	2	2	2	2	2	1	0%
10-Feb	3	3	2	3	3	3	3	1	50%
15-Feb	4	4	4	4	4	4	4	1	33%
18-Feb	7	7	7	7	7	7	7	3	75%
19-Feb	7	7	7	7	7	7	7	0	0%
20-Feb	7	7	7	7	7	7	7	0	0%
23-Feb	7	8	7	7	7	7	7	0	0%
25-Feb	7	8	7	7	8	8	8	1	14%
27-Feb	7	8	7	7	8	7	8	0	0%
01-Mar	7	8	7	7	8	8	8	0	0%
04-Mar	7	8	7	7	8	7	8	0	0%
09-Mar	7	8	7	7	8	8	8	0	0%

	Section 4: Constant Grow Tray - Height of Trials/Samples (cm)								
Dates	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Trial 6**	**Average**	**Change in Length**	**% Change in Length**
01-Feb	0	0	0	0	0	0	0	0	0%
03-Feb	0	0	0	0	0	0	0	0	0%
04-Feb	1	1	1	1	1	1	1	1	0%
07-Feb	2	2	2	2	2	2	2	1	0%
10-Feb	3	3	2	3	3	3	3	1	1%
15-Feb	4	4	4	4	4	4	4	1	0%
18-Feb	7	7	7	7	7	7	7	3	75%
19-Feb	7	7	7	7	7	7	7	0	0%
20-Feb	7	7	7	7	7	7	7	0	0%
23-Feb	7	8	8	7	7	8	8	1	0%
25-Feb	7	8	8	8	7	8	8	0	0%
27-Feb	7	8	8	8	8	8	8	0	0%
01-Mar	8	8	8	8	8	8	8	0	0%
04-Mar	8	8	8	8	8	8	8	0	0%
09-Mar	8	8	8	8	9	9	8	0	0%

#3. Photosynthetic Flotation Rate for Sections/Grow Trays (ET 50 - Effective Time 50)

The time it takes the leaves to float (minutes)	*Section 1 (2580 mg)*	*Section 2 (4000 mg)*	*Section 3 (1000 mg)*	*Section 4 (Constant)*
2	**0**	**0**	**0**	**0**
4	**0**	**0**	**0**	**0**
8	**1**	**0**	**0**	**1**
10	**4**	**0**	**0**	**3**
12	**5**	**1**	**4**	**5**
14	**7**	**3**	**5**	**5**
16	**9**	**5**	**6**	**6**
18	**10**	**8**	**7**	**9**
20	**10**	**10**	**10**	**10**

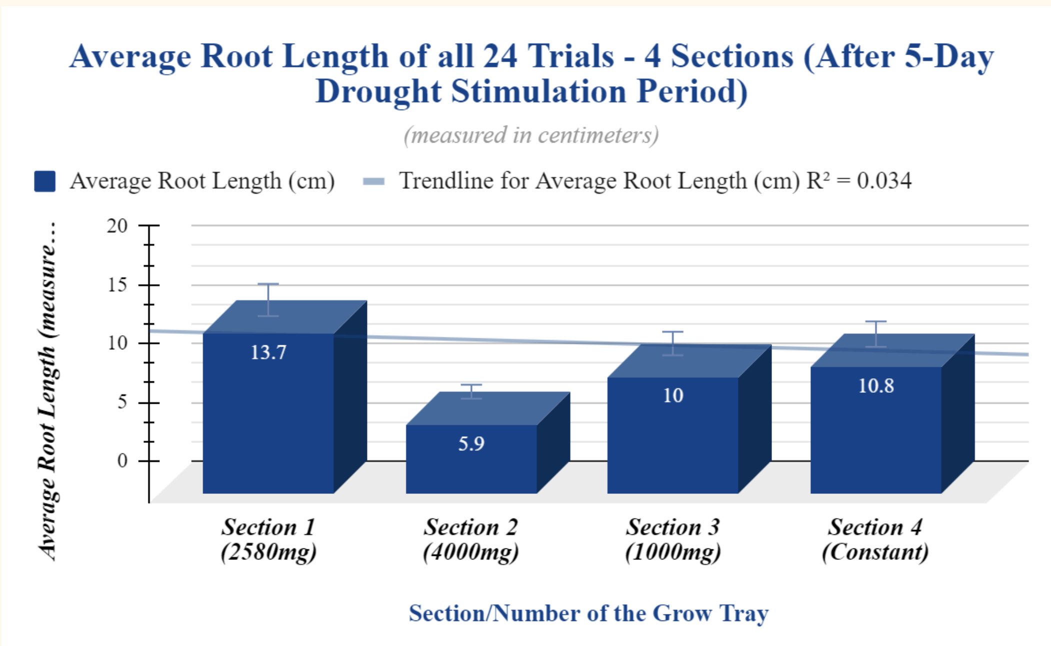


#4.1: Root Length of all 24 Trials (4 Sections) - Extracted After 8-Day Drought Period + 30-Day Growth Period (Height in centimetres) - No Graph Could be Made Due to Error with Google Sheets

	2580 mg Grow Tray - Heights of Trials/Samples						*4000 mg Grow Tray - Height of Trials/Samples*						*1000 mg Grow Tray - Height of Trials/Samples*						*Constant Grow Tray - Heights of Trials/Samples*					
Trial Number	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Tria 1 1	Tria 1 2	Trial 3	Tria 1 4	Tri al 5	Tri al 6	Tri al 1	Tri al 2	Tri al 3	Trial 4	Trial 5	Trial 6	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Tria 1 6
Height of Root Length (in cm)	14	13.4	13.7	13.8	13.6	13.7	8	10	12	11	10	9	5.9	5.8	6	6	5.8	5.9	10.8	10.8	10.8	10.8	10.6	11

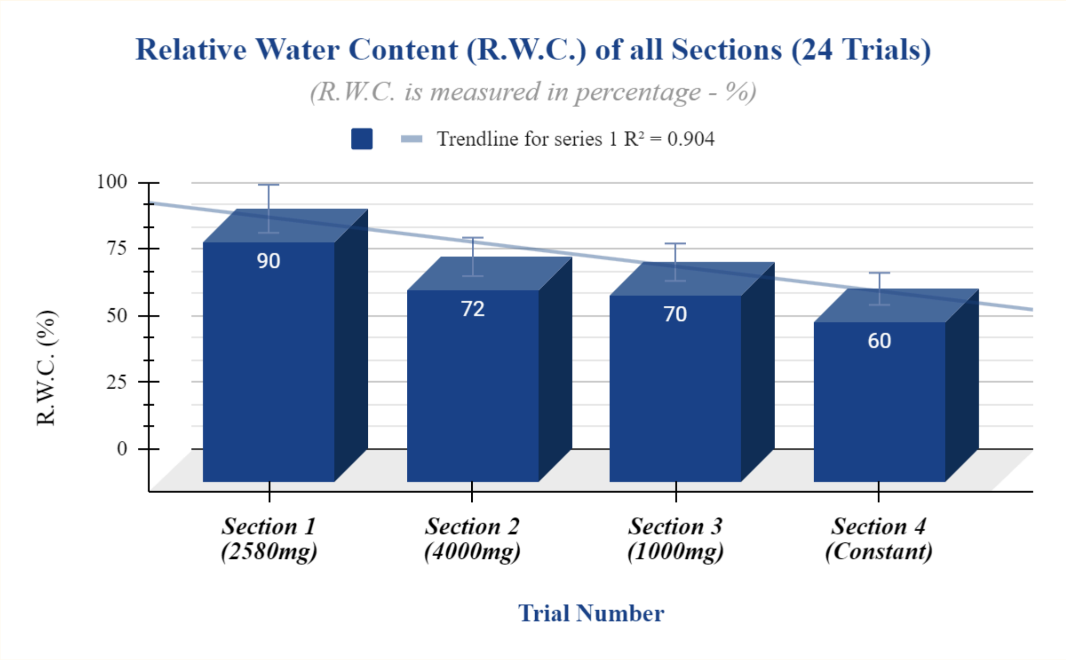
#4.2: Average Root Length of Sections (Measured in centimetres)

	Section (2580 mg)	*Section 2 (4000 mg)*	*Section 3 (1000 mg)*	*Section 4 (Constant)*
Average Root Length	13.7	5.9	10	10.8



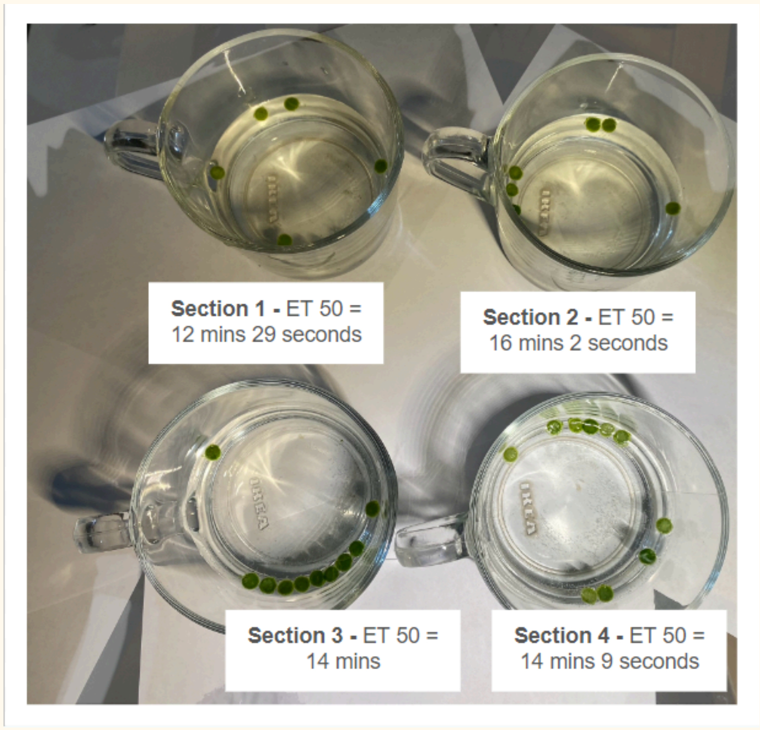
#5: R.W.C. *(Relative Leaf Water Content)* of 24 Trials - 4 Sections *(Measured in %)*

	Section 1 (2580 mg)	***Section 2 (4000 mg)***	***Section 3 (1000 mg)***	***Section 4 (Constant)***
R.W.C. (Relative Leaf Water Content) - Measured in %	90	72	70	60



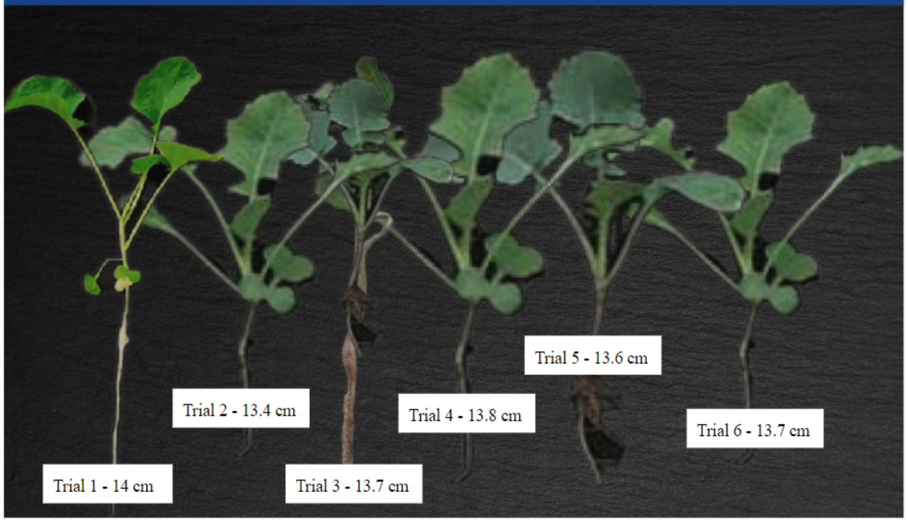
Qualitative/Quantitative Data of Metrics with Exception of Average Height/Leaf Count - Shown in Observations
(non-numeric i.e. text, video, photographs, etc)

Qualitative Data: Photograph of Photosynthetic Rate of Flotation (ET 50) for all Sections *- Videos can be seen in Google Slides Presentation*

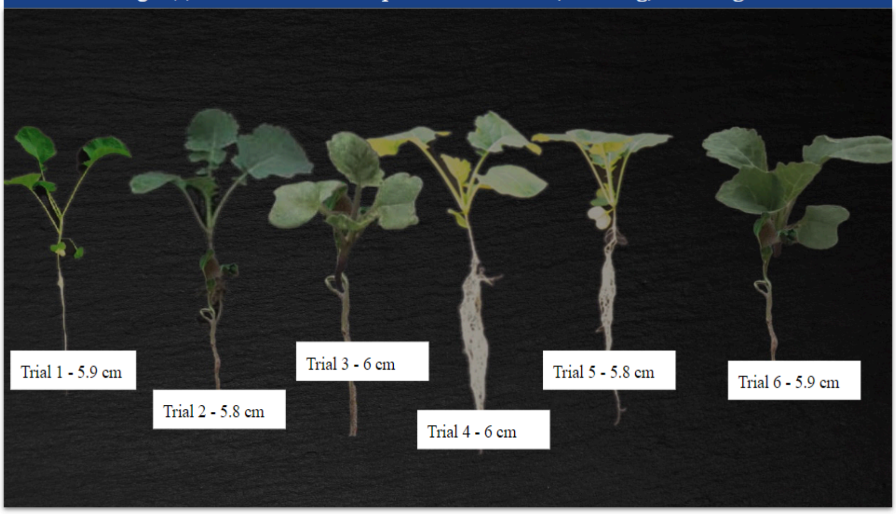


Qualitative Data: Photographs of Root Lengths of all 4 Sections *- Visual may Appear Blurry due to Computer Difficulties in Forming a Clear Image*

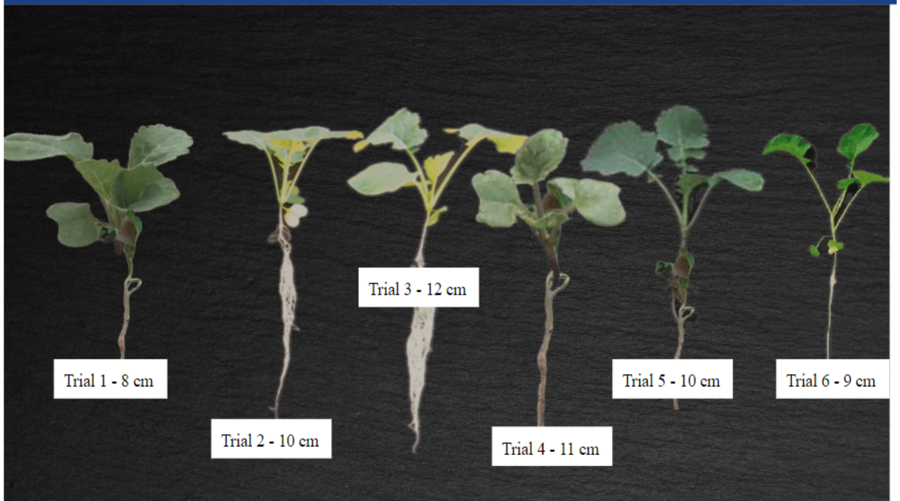
Root Length(s) of all 6 Trials/Samples of Section 1 **(2850 mg)** - *Average = 13.7 cm*

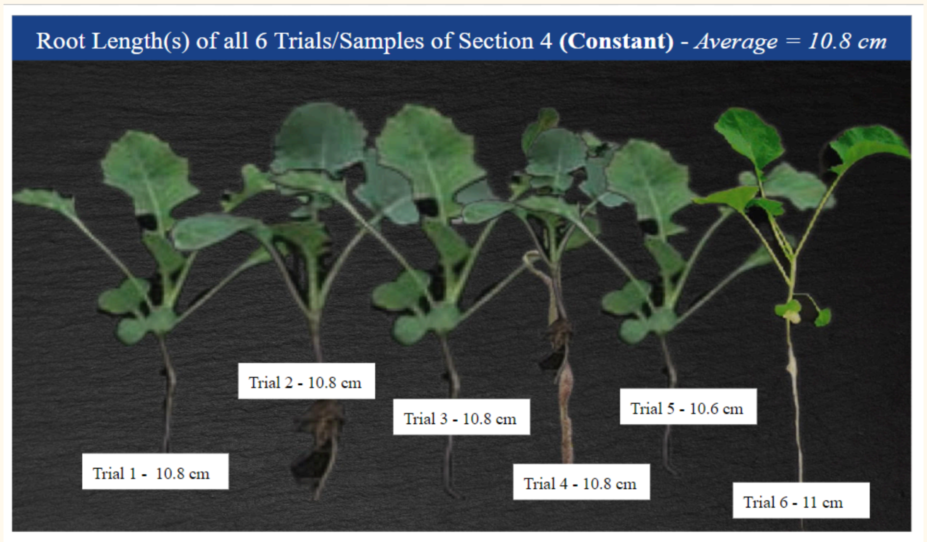


Root Length(s) of all 6 Trials/Samples of Section 2 **(4000 mg)** - *Average = 5.9 cm*

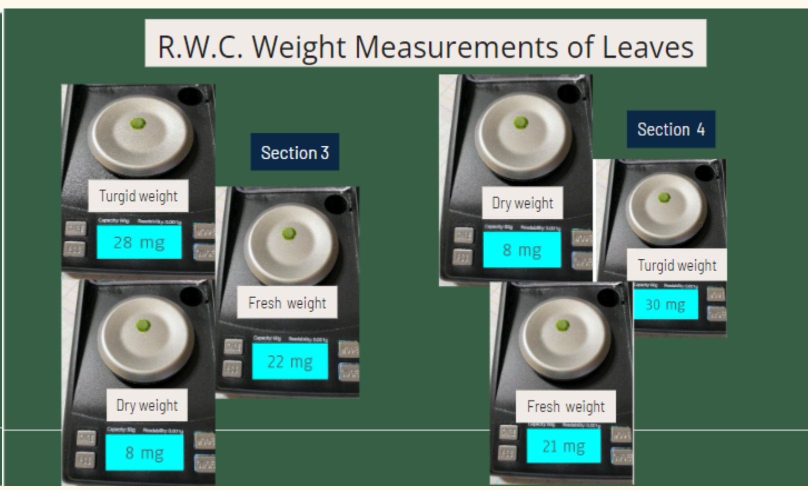


Root Length(s) of all 6 Trials/Samples of Section 3 **(1000 mg)** - *Average = 10 cm*

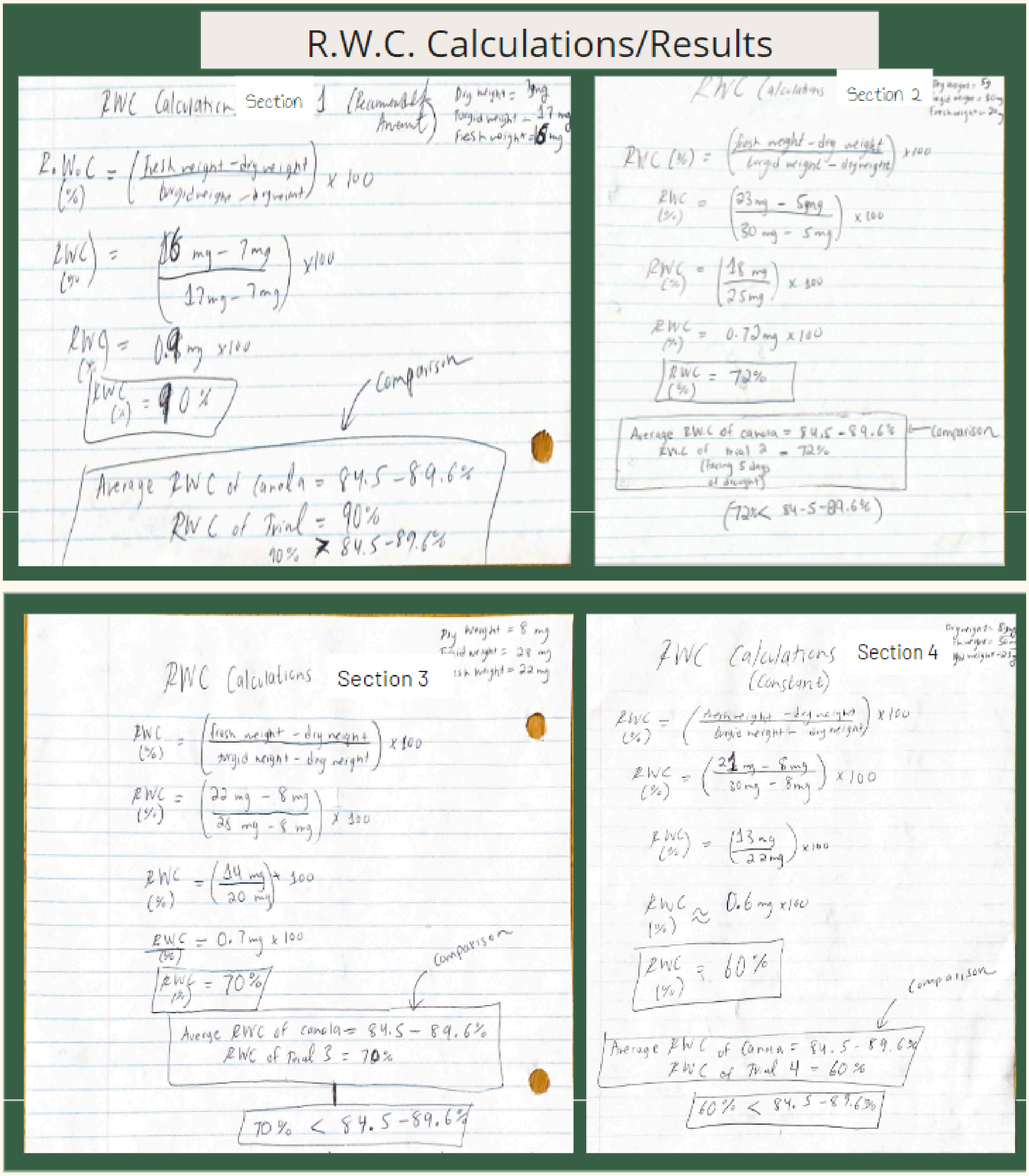




Qualitative Data: Leaf Relative Water Photographs of Weight Measurement of Leaves with Milligram Scale



Quantitative Data: R.W.C. Calculations (Numeric)



Results

No notable visible difference could be ascertained in the appearance of the canola seedlings after drought conditions had been imposed. The photosynthetic flotation, R.W.C., height (as well as average), and leaf count (average as well) results, however, indicated otherwise. The efficacy of the varied hydrogel amounts ranged from highly successful to less than ideal, as demonstrated by the results.

Section 1 (2850 mg) - Recommended/Hypothesised Amount

The ET 50 of the leaf discs of section 1 was 12 minutes and 26 seconds. This was faster than the average ET 50 time for canola plants by 2%, which established the highest rate of photosynthesis and R.W.C. of the hydrogels tested. The average height, leaf count, and root length respectively were 11 cm, 12 leaves, and 13.7 cm. The R.W.C. percentage was at 90% which was approximately 0.5% greater than the average R.W.C. of canola, which implies not only increasing water uptake but the overall response to water stress in canola. All of these metrics were higher than the required, in retrospect to the maturity of the canola itself (three-fourths on its way to maturity).

Section 2 (4000 mg) - Excess amount

The ET 50 of the leaf discs of section 2 was around 14 minutes. This was in between the average ET 50 times for canola plants, which established the second highest rate of photosynthesis and second R.W.C. of the hydrogels tested. The average height, leaf count, and root length respectively were 8 cm, 8 leaves, and 5.9 cm. The R.W.C. percentage was at 72% which was approximately 27% less than the average R.W.C. of canola, which implies not only slightly decreasing water uptake, but the overall response to water stress in canola, which shows an overall decline. All of these metrics were barely above average, in retrospect to the maturity of the canola itself (three-fourths on its way to maturity).

Section 3 (1000 mg) - Minimal amount

The ET 50 of the leaf discs of section 3 was around 16 minutes. This was in between the average ET 50 times for canola plants, which established the third highest rate of photosynthesis and third R.W.C. of the hydrogels tested. The average height, leaf count, and root length respectively were 8 cm, 8 leaves, and 10 cm. The R.W.C. percentage was at 70% which was approximately 19% less than the average R.W.C. of canola, which implies not only slightly decreasing water uptake, but the overall response to water stress in canola, which shows an overall decline. All of these metrics were average, in retrospect to the maturity of the canola itself (three-fourths on its way to maturity).

Section 4 (Constant) - No Hydrogel

The ET 50 of the leaf discs of section 3 was around 16 minutes. This was in between the average ET 50 times for canola plants, which established the third highest rate of photosynthesis and fourth R.W.C. of the hydrogels tested. The average height, leaf count, and root length respectively were 9 cm, 9 leaves, and 10.8 cm. The R.W.C. percentage was at 60% which was approximately 29% less than the average R.W.C. of canola, which implies significantly decreasing water content in the leaves, but the overall response to water stress in canola, which shows an significant decline. All of these metrics were below average, in retrospect to the maturity of the canola itself (three-fourths on its way to maturity).

Analysis

In simple terms, the 30-day growth period of the canola plants was fairly the same for all sections *(determined by pigment - majorly emerald green, average leaf count - 9, final average height 9 cm)*. This implies that the controlled variables are taking effect and are taking part in the controlling of certain metrics. It is safe to say that the average height of all the samples increased daily by 0.1-0.5 cm per day.

Throughout the 8-day drought simulation period, upon the hydrogel application *(on day 1)* and lighting conditions, it can be seen that there was no notable difference between the average heights and average leaf count, as the primary results would be internally inside the samples via the testing methods of R.W.C. and photosynthetic flotation. Like the 30-day growth period, the progress made was minimal by the average height (increased by about 0.1 cm) and leaf count (increased by 1). The respective average heights of sections (in cm) include 11, 8, 8, and 9 and the average leaf count includes 12, 8, 8, and 9.

R.W.C. and photosynthetic flotation are differentiated results to a larger degree. This proved the amount of hydrogels' resistance toward drought. The R.W.C. *(greater % of R.W.C., more leaf water content showing health under water stress)* respectively was 90%, 72%, 70%, and 60% which photosynthetic flotation *(lesser the time, the greater the rate of photosynthetic flotation)* was 12 mins, 16 mins, 14 mins, and 14 mins.

These results can be translated to the fact that the section order from least to most effective was Section 4, Section 3, Section 2, and Section 1. My hypothesis was correct at the beginning as section 1 showed an increase of R.W.C., in fact, more than the average R.W.C. of a canola plant and had an increase in average leaf count and height despite the drought conditions stimulated. This shows that the adequate/beneficiary amount of hydrogel is an amendment that aids a plant's water uptake during drought conditions as evidenced by the metrics of photosynthetic flotation, and R.W.C.

Conclusion

In conclusion, the application of hydrogel significantly influences the drought resistance of canola plants. Among the varied amounts tested, 2580 mg of natural-polymer hydrogel emerged as the most effective, exceeding expected outcomes. This is evident through key experimental metrics: Relative Water Content (R.W.C.), average height, average leaf count, average root length, and photosynthetic flotation (ET 50), which respectively measured at 90%, 11 cm, 12 leaves, 13.7 cm, and 12 minutes 26 seconds. Other sections exhibited lower metrics, indicating poorer health, with minimal differences in average height and leaf count but significant disparities in visible factors. The notable increase in R.W.C. in section 1 trials indicates enhanced water uptake, while the rise in leaf count and height signifies improved resistance to water stress. Comparison across sections, from least to most effective, ranks as follows: section 4, section 3, section 2, and section 1, based on comprehensive metrics assessing drought resistance. Therefore, the optimal amount of hydrogel for enhancing drought resistance in canola plants is 2580 mg.

Practical Applications/Extension:

- **Water Storage and Delayed Versioning:** Hydrogels can be added to the soil to boost water retention. This is especially advantageous in dry areas or during times of water constraint. The hydrogel absorbs and retains water, generating a reservoir that gradually delivers hydration to the plants, allowing them to weather dry spells.

- **Improved soil structure:** Hydrogels can improve soil structure by increasing aggregation and decreasing erosion. This improves the infiltration of water and root permeation, which is critical for drought-prone locations.

- **Nutrient Retention:** Hydrogels can be constructed to collect and hold nutrients, preventing them from seeping into the soil. This improves the accessibility of nutrients to canola plants, supporting growth even amid water constraints.

- **Seed Coatings:** The coating of seeds via hydrogel compositions before planting can improve germination and establishment of seedlings. The hydrogel can preserve the seeds, allowing the seedlings to get a better start even in conditions of drought.

- **Drought-responsive watering frameworks:** Smart watering systems with hydrogels can be created. These devices can adapt to soil levels of moisture, discharging the retained water from the natural polymer hydrogels whenever necessary, thus optimizing water efficiency.

- **Study on Hydrogel Formulations:** Continuous research into developing hydrogel compositions, particularly for canola plants may bring greater benefits. Hydrogels may be tailored to satisfy canola's unique water and nutritional requirements, increasing its efficacy in drought-prone regions.

- **Practical Trials and Evaluation:** Field experiments in various climates, as well as analyzing the growth rate of hydrogel-treated canola crops, can give vital information on the technology's real-world usefulness.

- **Affiliation with Agricultural Extension Service:** Collaborating with extension and agricultural agencies to teach farmers about the numerous advantages and correct use of hydrogels can help this technology become more widely adopted. By investigating these applications and expansions, the implementation of natural polymer hydrogels in canola production can greatly improve drought tolerance and overall crop yield.

Sources of Error

1. **Human error -** fault in the measurements recorded for the average height or the calculations done for the R.W.C.

2. **Machine error** - pH, EC, or temperature metre would have malfunctioned due to the slope of the electrode being high in high temperatures, potentially impacting the reading or the milligram scale could've shown a wrong reading of measurement

3. **Contamination:** Contamination of experimental setups, soil, or hydrogel solutions can introduce unwanted variables.

4. **Inconsistent Watering Regime:** Variations in the watering schedule can affect the results. Implement a consistent and well-controlled watering regime for all plants throughout the experiment.

5. **Inconsistent Environmental Conditions:** Variability in temperature, humidity, and light conditions. Can affect plant growth.

How Can I Improve My Experiment?

1. Make sure to measure and apply hydrogels carefully across all treatment groups to ensure consistency in how water is retained. Using accurate equipment and following standard methods can help achieve reliable results.
2. Design experiments with enough replication and randomization to ensure that any observed effects are statistically valid. It's important to consider factors like soil type, plant growth stage, and environmental conditions to set up experiments well.
3. Keep environmental conditions stable to avoid outside factors affecting plant growth and water uptake. This might mean using controlled environments like greenhouses.
4. Before starting experiments, study the soil, hydrogel formulations, and canola plants thoroughly to establish a baseline for comparison and ensure accurate interpretation of results.
5. Monitor plant growth, water usage, and responses to drought and hydrogel treatment over a long period to see how effects develop over time.
6. Use advanced statistical techniques to analyze the data and understand the relationships between hydrogel application, drought stress, and canola plant performance.
7. Look into molecular biology tools to understand the biological mechanisms behind how hydrogels affect canola plants' response to stress.
8. Test findings in real-world field conditions to see if they hold up outside the lab. Working with farmers and other experts can help set up experiments that reflect actual agricultural practices.

Future Plans:

1. Improving Hydrogels: Making better hydrogels that can hold more water, specifically tailored for canola. This could mean testing out new materials, tweaking the chemical makeup, or even changing the structure on a tiny scale to squeeze out the most water retention.
2. Different Ways to Apply Hydrogels: There's a need to figure out the best ways to put these hydrogels on canola plants, whether that's spraying them on the leaves, mixing them into the soil, or coating the seeds. Different methods might work better depending on the soil and climate conditions.
3. Real-world Testing: Large-scale trials in actual fields will be essential to see if hydrogels truly make a difference in helping canola deal with drought. Keeping an eye on how the crops grow, how much water they use, and what impact it has on the environment.
4. Pairing with High-Tech Farming: Combining hydrogel use with fancy farming tech, like sensors and data analysis, could be a game-changer. These tools can help farmers track soil moisture levels and fine-tune their watering, making sure the hydrogels are doing their job effectively.
5. Making It Practical: Scaling up production and getting hydrogels out to farmers at a reasonable cost will be crucial. Building partnerships with industry players and figuring out how to distribute these products effectively will be key steps.

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