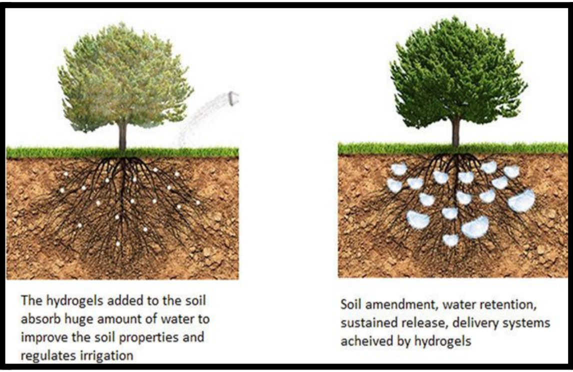

Arid Plants Mask Drought: *Exploring the Effects of Varied Amounts of Natural Polymer Hydrogel in Enhancing Drought Resistance in Canola* - Do the Different Amounts of Natural Polymer Hydrogel Enhance Drought-Resistance in Canola Plants?

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Grade: 9
School: Khalsa School Calgary

Project Type: Experimental
Category: Life Sciences/Biology/Agriculture

Testable Question:

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

Special Note:

- A lot of information was omitted to ensure the presentation was as concise as possible

- All relevant/additional information can be seen in my logbook that will be given in the platform or in the in-person fair

This experiment aims to find the most effective amount of natural-polymer based hydrogel to enhance drought resistance of canola plants to mask the drought crisis in Alberta.

- **Objective:** Applying a greener solution to mask drought conditions in canola plants via hydrogel.

Background Research - *(Refer to Works Cited Slide for Reference)*

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…" (Adjuik et al., 2022).

Image inserted from:
https://link.springer.com/referenceworkentry/10.1007/978-3-030-76523-1_5-1

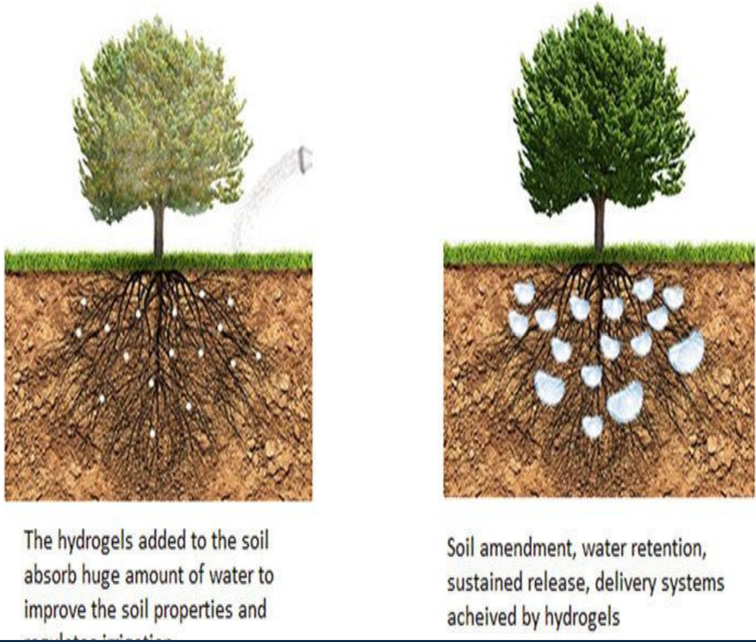


Fig. 1 —Application of hydrogel to soil/roots of a mature tree to give run-down of what goes on below the soil. Available: https://link.springer.com/referenceworkentry/10.1007/978-3-030-76523-1_5-1

Hydrogel - An Overview

- Natural and polymer based
- Relatively inexpensive
- A renewable resource (produced through biomass)
- Natural, polymer hydrogel is non-toxic and biodegradable

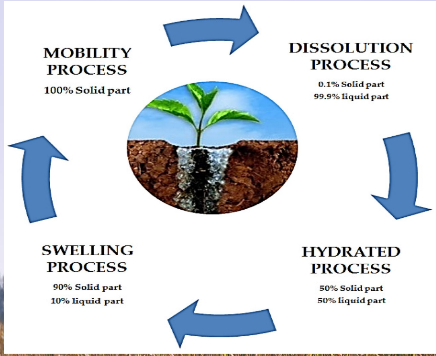
Applied by mixing the hydrogel within 3 cm of the topsoil (with ruler). This application process could be a consideration for future experimentation and improvement.

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

- Its' water retention properties: "Hydrogels increase the plants' uptake of water and its availability, mainly during drought conditions…" (Tariq et al., n.d.).

Recommended amount of Hydrogel for Crops (No Research on Canola has been done)

"…for almost all types of crops to soil type and climate, a meagre application rate of hydrogel i.e. 2.5-5.0 Kg/ha is effective" (Yadav & Kumar, 2023). *This translates to 2580 mg for 1036 cubic centimeters.*



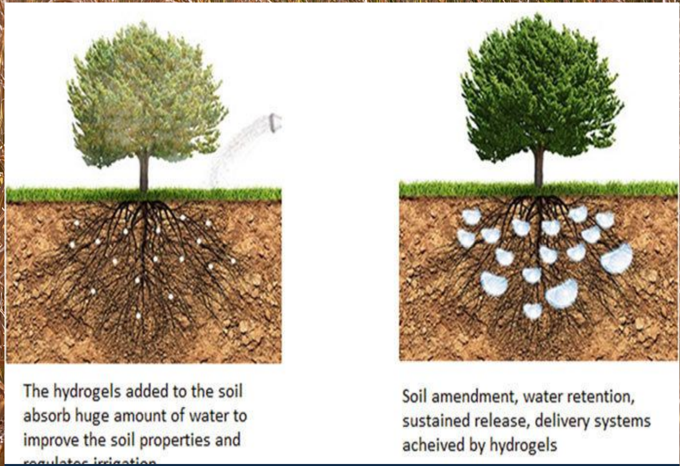


Fig. 1 —Application of hydrogel to soil/roots of a mature tree to give run-down of what goes on below the soil.

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

2580 mg: 1036 cubic centimeters of soil (Section 1)	***4000 mg:1036 cubic centimeters of soil (Section 2)***	***1000 mg:1036 cubic centimeters of soil (Section 3)***	***Constant (No Hydrogel):1036 cubic centimeters of soil (Section 4)***
It was the recommended amount for all crops *(this was backed up by research which can be seen in the hypothesis).*	Wanted to see how excess amounts of hydrogel would impact the health.	Wanted to see how limited amounts of hydrogel would impact health.	Aligns with the situation of treating today's "*drought prevention." Also constant sections help increase validity and accuracy of data.*

FIG. 2 - Drought of canola in Alberta: Why this issue is so important and can impact the economy and overall agriculture industry as an entirety. Available: https://www.producer.com/news/flash-droughts-can-pose-risk-to-crop-production/

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

- Alberta's most produced crops
- "Recent drought conditions in Western Canada have led to catastrophic yield losses of canola in some areas…" (*Generation of Canola Lines with Increased Heat and Drought Tolerance by Regulating Phospholipid: Diacylglycerol Acyltransferase Activity*, n.d.)
- Needs a sustainable solution to mask the agricultural drought it is facing.

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 in 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. Otherwise, a typical drought would last for months.

FIG. 3 - 4 Types of Drought and Their Description. Available: https://www.researchgate.net/figure/Classification-of-different-types-of-droughts_fig1_362955984

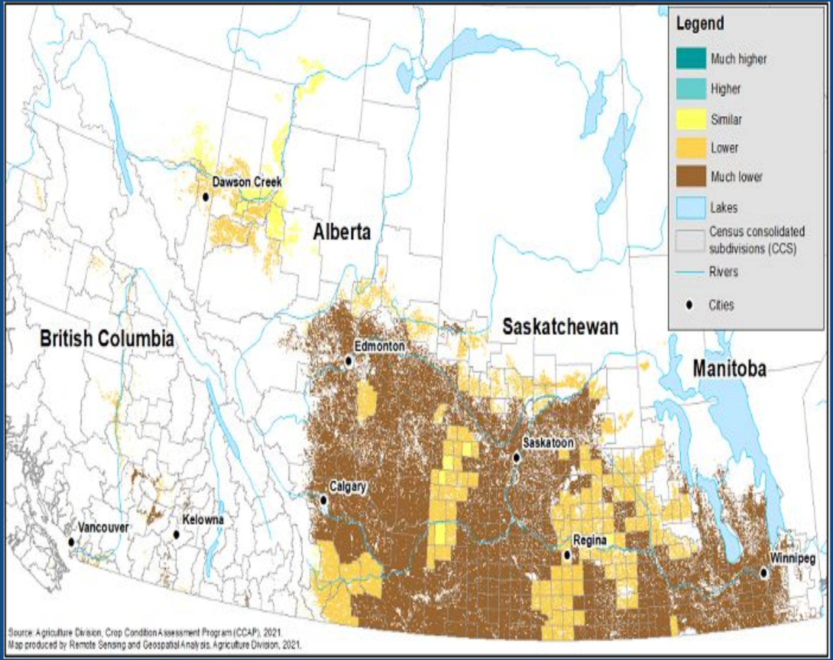


FIG. 4 - Statistical Data of Moisture Index of Canola Plants across parts of Western Canada (including Alberta) - Source in the excerpt on the left bottom of the image

Canola Yield Over Drought Period - Much Lower than Past Years

- Moisture level of Alberta (and other neighbouring provinces) has been less and decreased significantly throughout the past years

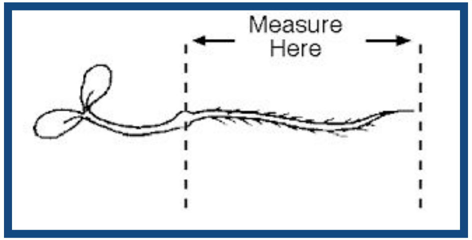
- Another reason behind this project in finding a feasible solution to mask drought resistance in crops via hydrogel.

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

Name	Measurement
EC (Electrical Conductivity)	4 mS/cm
pH	5.5
ppm (parts-per-million)	25 ppm
Required Amount of Water (By Alberta's Government)	4-5 inches of water = 150 mL (daily for 24 samples)

What Parameters will be used to Measure Drought Resistance?

Name of Parameter	Brief Description (Steps)	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" (*Photosynthetic Floatation*, 2019)	The rate of photosynthesis changes in plants when they undergo drought (the lesser the ET, the greater the photosynthetic flotation). 
Leaf Relative Water Content (RWC)	"Leaf relative water content (RWC) is an indicator of water status in plants…" (Lugojan and Ciulca 2011). (Calculated by a formula). 	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" (Juenger & Verslues, 2022).

Root Length (cm)	Length of the plant's leaves, often measured from the longest root.  	*"Plants with longer 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 trial since there will be 24 samples.	The height shows the health/productivity under the drought condition.

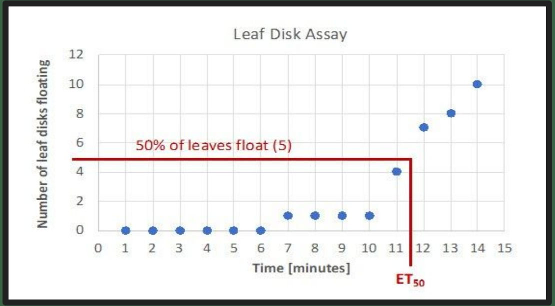
How to Calculate R.W.C and Photosynthetic Flotation (Very Brief Steps - More Information in Logbook)

USING A FORMULA FOR R.W.C.

Leaf relative water content (RWC) (%):

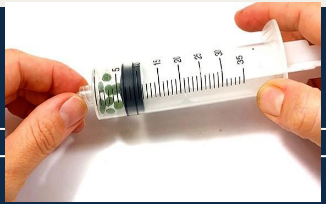
$$RWC(\%) = \left[\frac{(fresh\ weight - dry\ weight)}{(turgid\ weight - dry\ weight)}\right] \times 100$$

EFFECTIVE TIME FOR LEAF DISK FLOTATION



STEPS OF PHOTOSYNTHETIC FLOTATION (FORMULA WRITTEN TO EXPLAIN R.W.C.)

“To test the efficacy of the hydrogels, I used the method of photosynthetic flotation. First, create 10 leaf discs of trial by making leaf discs of each trial and putting them in the needless syringe.. After drawing some buffer solution into the syringe (0.2% baking soda solution with dish soap) apply a vacuum by plugging the opening with a fingertip and pulling the plunger for 10 seconds. Release the plunger abruptly 2-3 times so that gasses could be fully extracted from the leaves. This will cause the discs to sink to the bottom of the syringe. Lightly tap the syringe to expel excess air, and pour the leaf discs into a clear cup of 150 mL of the buffer solution. Place the cup approximately 20 cm underneath an LED light and keep it there until all discs. Record the ET 50 (effective time in which 50% of the discs float to the top).The faster they reach the surface, the more efficient the rate of photosynthesis is from quicker oxygen production” (Exploratorium, n.d.).



STEPS OF CALCULATING R.W.C. (RELATIVE LEAF WATER CONTENT)

Method Derived from Penn. State University

Punch three leaf disc that is 1 cm wide for one sample of each section with a single-leaf hole puncher. Store 1 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)*. 4 in total for each weight taken, for each section. 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. After the samples are fully hydrated, decant the leaf discs. Dry the surface of the leaf discs gently with a towel. Weigh the turgid weight of the leaf discs with a milligram scale *(to the nearest milligram)*. Oven-dry the leaf discs at 80 degrees Celsius for a period of 24 hours. Weigh the dried leaf discs to the nearest milligram. 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) (%):

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

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

Introduction of Scientific Method (Hypothesis, Variables, Procedure, etc)

Hypothesis

- Hydrogel suggested as soil additive to increase water availability to crops under drought stress without releasing undesirable byproducts (Mazloom et al., 2020).
- Recent arid conditions in Western Canada led to catastrophic yield losses of canola (Generation of Canola Drought Tolerance by Regulating Phospholipid, n.d.).
- Hydrogel may enhance drought resistance, offering an eco-friendly option for crop productivity under water scarcity (Yadav & Kumar, 2023).
- Recommended hydrogel application rate: 2580mg/1030 cm^3 (Yadav & Kumar, 2023).
- Hypothesized metrics for assessing drought resistance: R.W.C., root length, plant height, and photosynthetic rate (Yadav & Kumar, 2023).
- Research suggest that 2580 mg:1030 cm^3 hydrogel application enhances drought resistance the most (Yadav & Kumar, 2023).
- In response to these metrics, it is hypothesized that trials with the applied hydrogel with have an R.W.C. (leaf relative water content - in %) 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).

Variables

Responding Variable (Dependent Variable)

Parameters to measure drought resistance:

- Photosynthetic flotation (Effective Time: "ET_{50}")
- Leaf Relative Water Content (RWC)
- Root length (cm)
- Average/all leaf count and leaf count of all Trials
- Average/all height of samples and height of all samples (in cm)

Independent Variable (Manipulated Variable):

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

In all trials, the hydrogel was mixed with the first 3 cm of topsoil - used ruler to ensure.

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 trial (no hydrogel at all)

Controlled Variable:

- **Temperature:** 19°C
- **Canola seeds per tray:** 6 (24 IN TOTAL FOR 4 SECTIONS)
- **Type of canola:** Non-GMO, organic, and open-pollinated
- **Quantity of soil per tray (trial):** 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 nitrogen-based
- **Number of leaf disks per trial for testing photosynthetic flotation:** 10
- **Number of leaf disks per trial 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 mS/cm
- **ppm (parts-per-million) of irrigation water:** 25

Materials:

Materials Required for Growing Canola:

Granular hydrogel (natural 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

Materials Required to Measure Leaf Relative Water Content:

Single-hole puncher
Deionized water (DI water)
Airtight container (4)
Plant discs of the canola leave - 5 leaf discs of each trial (20 in total)
Single-hole puncher
Milligram scale
Disposal of drying oven

Materials Required to Measure Photosynthetic Flotation:

Needless syringe (20 cc/mL)
Plant discs of the canola leave - 10 leaf discs from each trial (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)

Measurement tools:

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

Methodology (Procedure + Materials)

The main materials I used included: canola seeds, a grow environment (soil and water plus other controlled variables), hydrogel, photosynthetic flotation and R.W.C. materials, ruler, and a milligram scale. For testing I used a non-GMO, organic variety of canola seeds. They were received as seeds and grown in biodegradable grow trays and standard loam soil *(1036 cubic centimeters).* The seeds experienced a lighting cycle of 12 hours of light and dark and were situated roughly 3 inches apart from each other. An average temperature of 19℃ was maintained, and seeds were watered daily with 150 mL during the pre-testing growth period of 30 days until plants were approximately three-quarters of the way to maturity. Four trays/trials of 6 canola plants were grown. *The heights were taken as data as well as observations to make sure the controlled variables were allowing the same height for all the samples. Observations were taken during the 30-day growth period.*

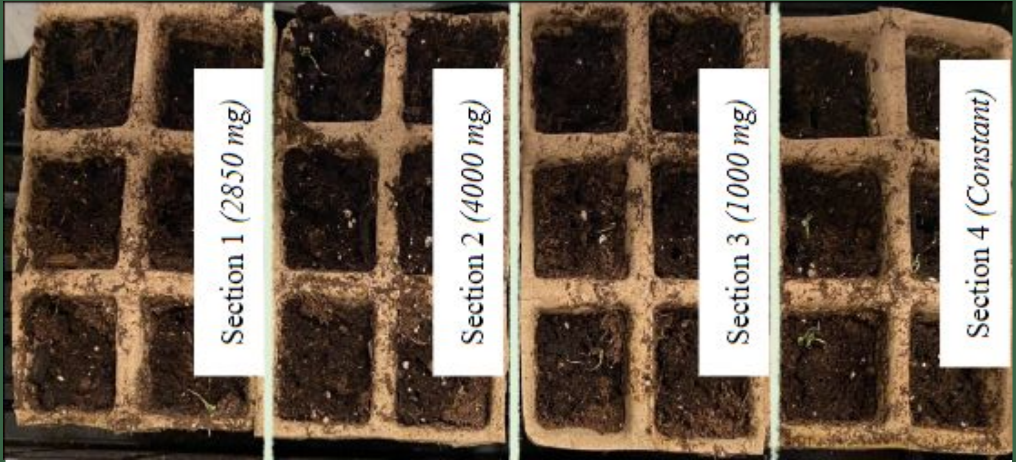
After the 30-day growth period, for eight days, the regular watering system of the samples was halted to allow application of the hydrogel and to stimulate the drought conditions. The seedlings received nothing other than the consistent light and temperature conditions of the chamber. The R.W.C. was calculated by the formula, the photosynthetic flotation (effective time) was measured, average height, number of leaves, and root length *(refer to background research on the steps for each metric)*. After this, data was recorded coming to a conclusion that the recommended amount (2580 mg) enhanced drought resistance in canola the most (due to highest average height, leaves, R.W.C. (%), and ET50 (photosynthetic flotation) - 7.8 cm, 9, 90%, slightly more than 12 minutes.

Data Collection + Observations

(Qualitative - *Photographs*/Description of Observation During Respective Date and Quantitative - numerical data exhibited in a table/graph format or just any data shown as numbers)

Submersion of Seeds in Water (24 Hours) + Day 1 of Growth Period (20 Days)

non-GMO, organic canola seeds in water for 24 hours to improve the germination rate of the seeds.

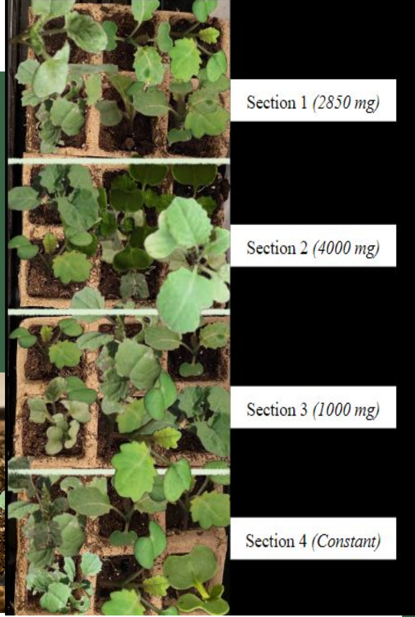


On the 1st day the 24 seeds (6 in each of the 4 sections) were transplanted 5 mm under the soil to ensure the seeds would sprout. There was no growth recorded as it only was the first day of the growth period.

Day 5 and 10 of the 30-Day Growth Period

Day 5: 80% of samples grew, average leaf count was 3, and nearly all samples were bright green in pigment (fairly healthy). Average height of sections:

Section 1 (*Recommended*): 0.3 cm
Section 2: 0.3 cm
Section 3: 0.3 cm
Section 4 (*Constant*): 0.3 cm



Day 10: Fairly same as the Day 5 with the exception of average height (below), leaf count (4), and pigment (darker). 90% of the samples grew. Average height of sections:

Section 1 (*Recommended*): 5 cm
Section 2: 5 cm
Section 3: 5 cm
Section 4 (*Constant*): 5 cm

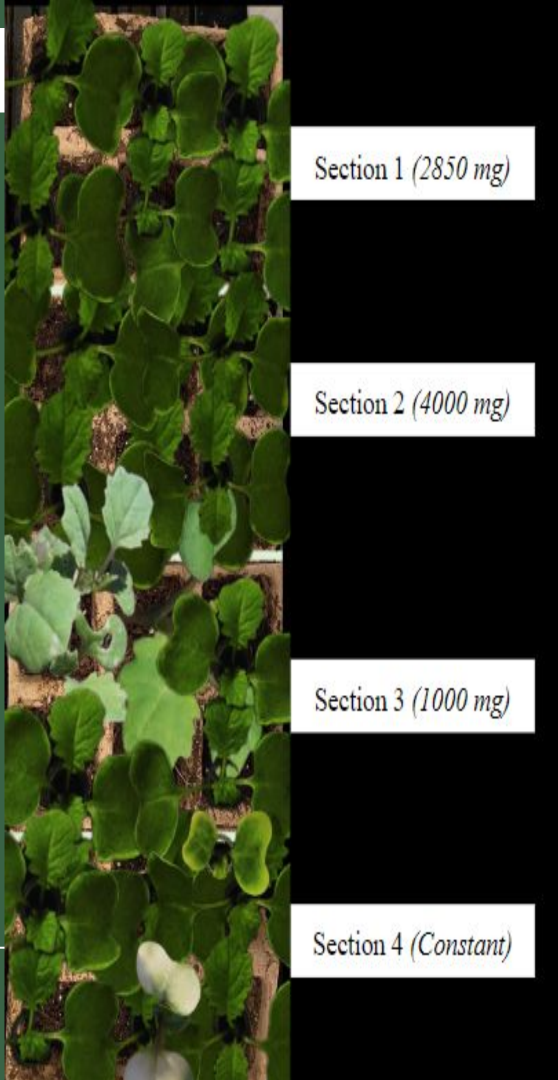
Day 15 and 20 of the 30-Day Growth Period

Day 15: 95% of samples grew, average height for all samples were 6.9 cm, leaf count was 4, and nearly all the samples were exceptionally healthy.

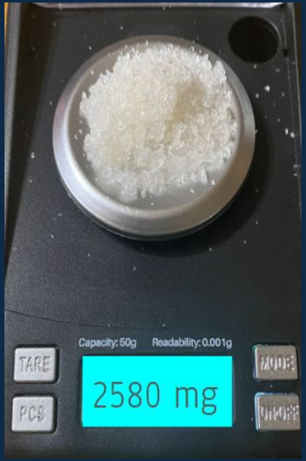
Day 20: All of the samples had grown by then, average height for all sections is 7.5 cm, leaf count is 7 leaves, and all are surprisingly healthy. From this I can hypothesize that my controlled variables are actually working.

Day 30 of 30-Day Growth Period

Day 30: All of the samples had grown by then, average height for all sections is 10 cm, leaf count is 9 leaves, and all are surprisingly healthy. From this I can hypothesize that my controlled variables are actually working showing a successful growth period.



Day 1 and 3 of Drought Stimulation + Hydrogel Application Period (8 Days)



Day 1: Average height and leaf count was the same. No notable difference could be seen upon the hydrogel application at it would take time to settle.

Day 3: Fairly same as the Day 1 with the exception of average height (below), leaf count (8), and pigment (darker). Average height of sections:

Section 1 (*Recommended*): 7.6 cm
Section 2: 7.5 cm
Section 3: 7.6 cm
Section 4 (*Constant*): 7.5 cm

Day 5 of Drought Stimulation + Hydrogel Application Period

Day 5: Average height of sections:

Section 1 *(Recommended)*: 7.8 cm
Section 2: 7.5 cm
Section 3: 7.6 cm
Section 4 *(Constant)*: 7.7 cm

Day 5: Average leaf count of sections:

Section 1 *(Recommended)*: 9
Section 2: 7.
Section 3: 7
Section 4 *(Constant)*: 8

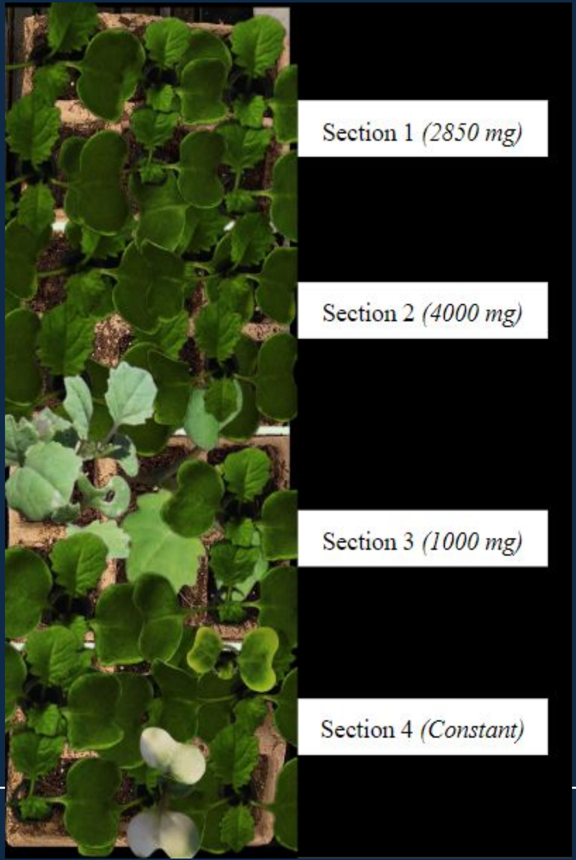
Day 8 of Drought Stimulation + Hydrogel Application Period - FINAL DAY OF READINGS

Day 8: Average height of sections:

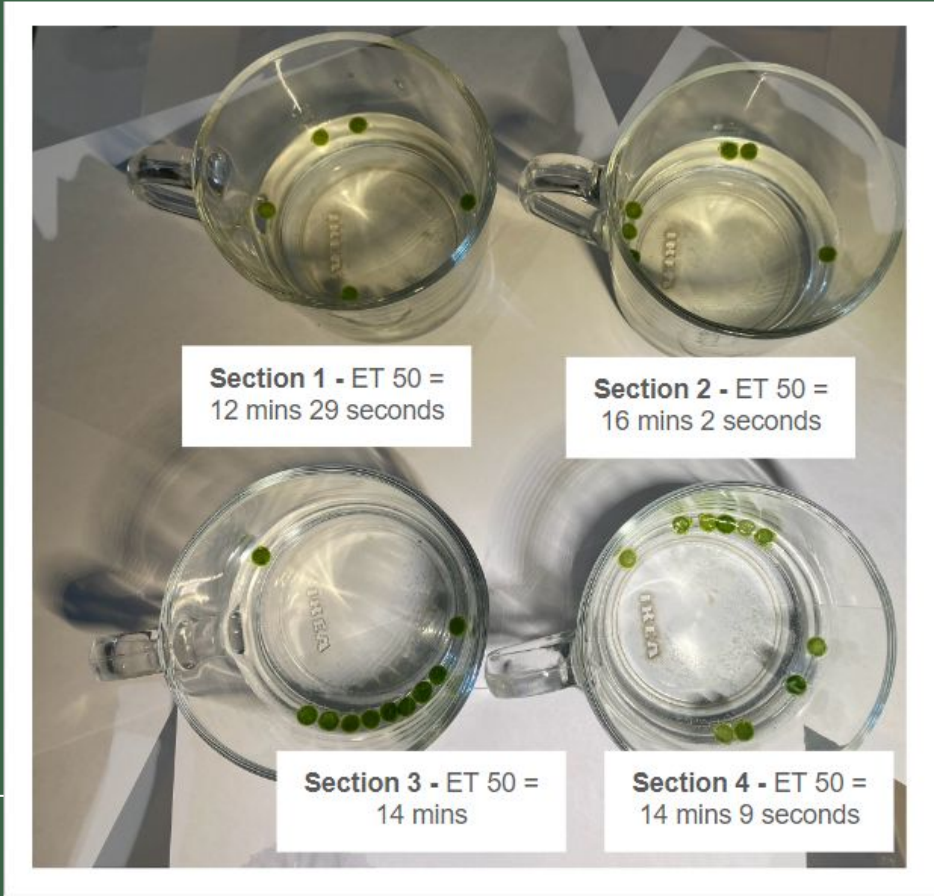
Section 1 *(Recommended)*: 11 cm
Section 2: 9 cm
Section 3: 9 cm
Section 4 *(Constant)*: 9 cm

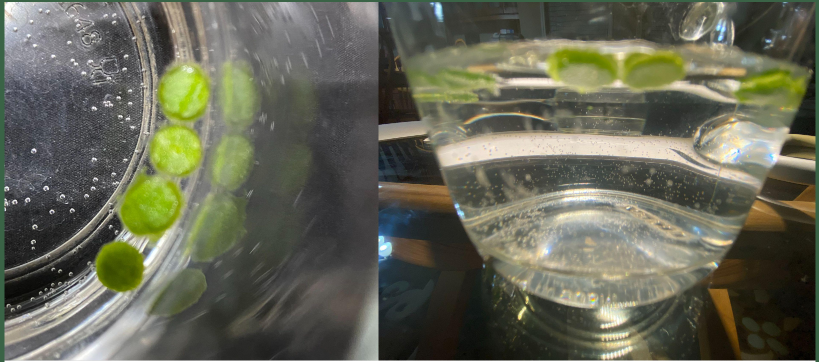
Day 8: Average leaf count of sections:

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



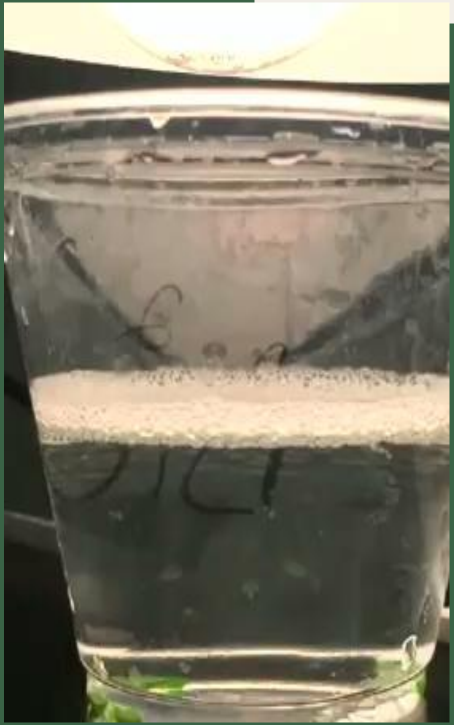
Photosynthetic Flotation Results (ET 50)





Close-up of some leaf discs in the buffer solution

Photosynthetic Flotation Results (ET 50) Time Lapse Video of all Sections



Section 1 (Recommended - 2580 mg) - ET 50 - 12 mins. and 29 secs.

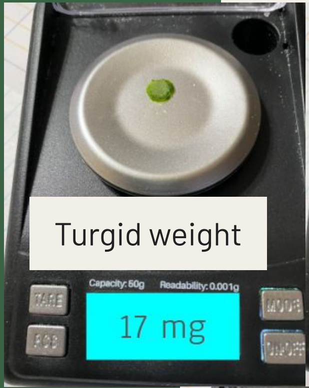
Section 2 (4000 mg) - ET 50 - 16 mins. and 26 secs.

Section 3 (1000 mg) - ET 50 - 14 mins. and 0 secs.

Section 4 (Constant - No Hydrogel) - ET 50 - 14 mins. and 9 secs.

R.W.C. Weight Measurements of Leaves

Section 1



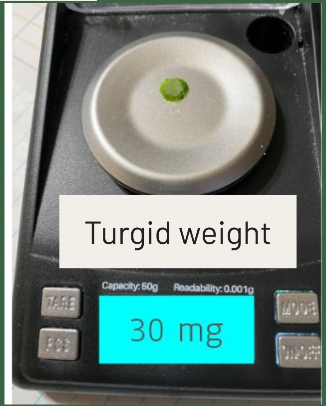
Turgid weight

Fresh weight

Dry weight

Section 2

Dry weight



Turgid weight

Fresh weight

Leaf disc in DI water (turgid weight)

R.W.C. Weight Measurements of Leaves

Section 3

Turgid weight

28 mg

Fresh weight

22 mg

Dry weight

8 mg

Section 4

Dry weight

8 mg

Turgid weight

30 mg

Fresh weight

21 mg

R.W.C. Calculations/Results

RWC Calculation Section 1 (Recommended Amount)

Dry weight = 7mg
Turgid weight = 17 mg
Fresh weight = 16 mg

$$R.W.C\ (\%) = \left(\frac{\text{Fresh weight} - \text{dry weight}}{\text{turgid weight} - \text{dry weight}}\right) \times 100$$

$$RWC\ (\%) = \left(\frac{16\ mg - 7\ mg}{17\ mg - 7\ mg}\right) \times 100$$

$$RWC\ (\%) = 0.9\ mg \times 100$$

$$RWC\ (\%) = 90\%$$

Comparison

Average RWC of Canola = 84.5 – 89.6%
RWC of Trial = 90%
90% > 84.5 – 89.6%

RWC Calculations Section 2

Dry weight = 5g
Turgid weight = 30mg
Fresh weight = 23mg

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

$$RWC\ (\%) = \left(\frac{23\ mg - 5\ mg}{30\ mg - 5\ mg}\right) \times 100$$

$$RWC\ (\%) = \left(\frac{18\ mg}{25\ mg}\right) \times 100$$

$$RWC\ (\%) = 0.72\ mg \times 100$$

$$RWC\ (\%) = 72\%$$

Average RW.C of canola = 84.5 – 89.6% ← Comparison
RW.C of trial 2 = 72%
(facing 5 days of drought)

(72% < 84.5 – 89.6%)

RWC Calculations — Section 3

Dry weight = 8 mg
Turgid weight = 28 mg
Fresh weight = 22 mg

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

$$RWC\ (\%) = \left(\frac{22\text{ mg} - 8\text{ mg}}{28\text{ mg} - 8\text{ mg}}\right) \times 100$$

$$RWC\ (\%) = \left(\frac{14\text{ mg}}{20\text{ mg}}\right) \times 100$$

$$RWC\ (\%) = 0.7\text{ mg} \times 100$$

RWC (%) = 70%

comparison

Average RWC of canola = 84.5 – 89.6%
RWC of Trial 3 = 70%

70% < 84.5 – 89.6%

RWC Calculations (Constant) — Section 4

Dry weight = 8 mg
Fresh weight = 30 m
Turgid weight = 21

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

$$RWC\ (\%) = \left(\frac{21\text{ mg} - 8\text{ mg}}{30\text{ mg} - 8\text{ mg}}\right) \times 100$$

$$RWC\ (\%) = \left(\frac{13\text{ mg}}{22\text{ mg}}\right) \times 100$$

$$RWC\ (\%) \approx 0.6\text{ mg} \times 100$$

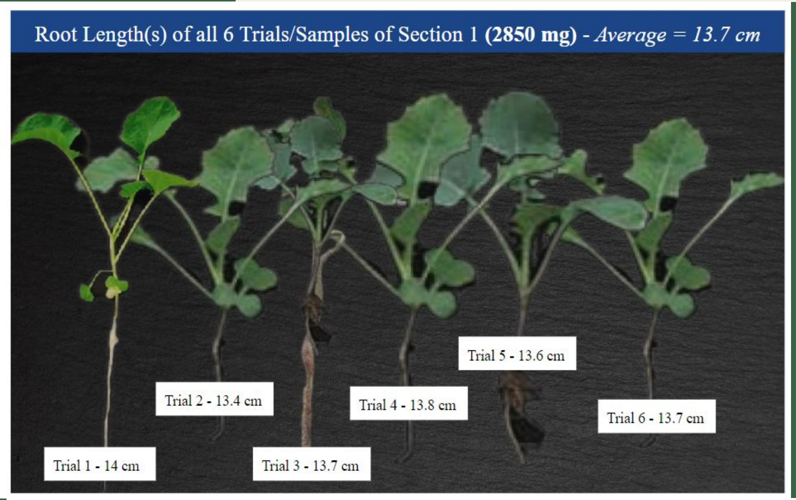
RWC (%) = 60%

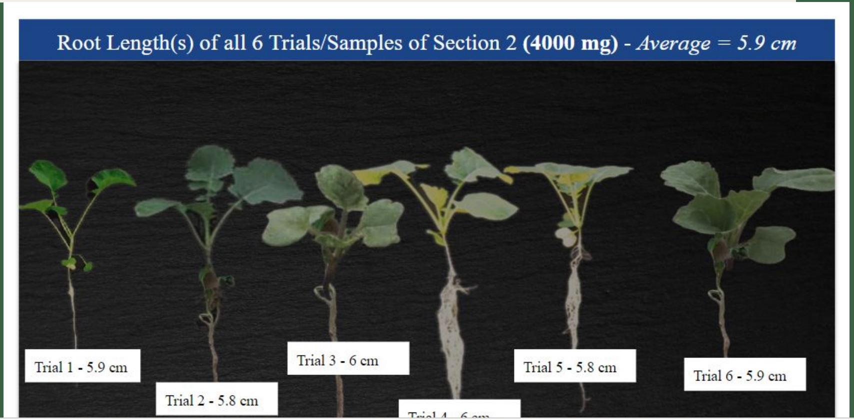
comparison

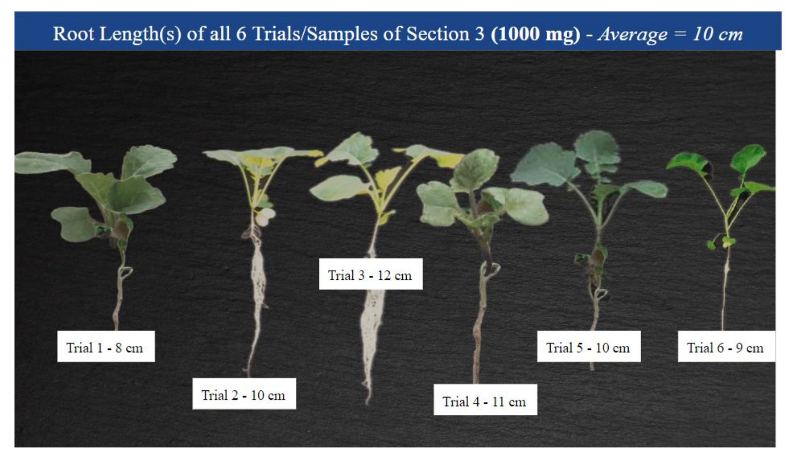
Average RWC of Canola = 84.5 – 89.6%
RWC of Trial 4 = 60%

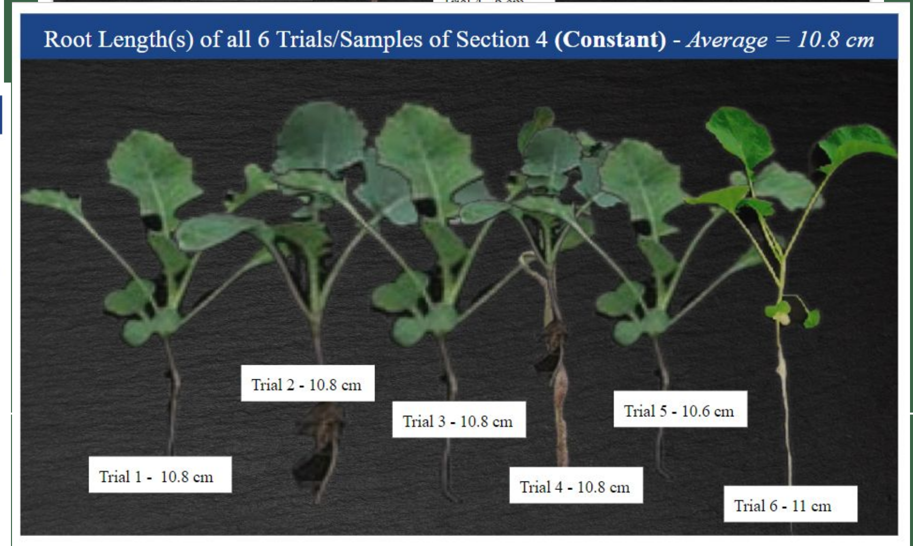
60% < 84.5 – 89.6%

Root Length of 4 Sections (24 Trials)









Statistical Data of the Experiment

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

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

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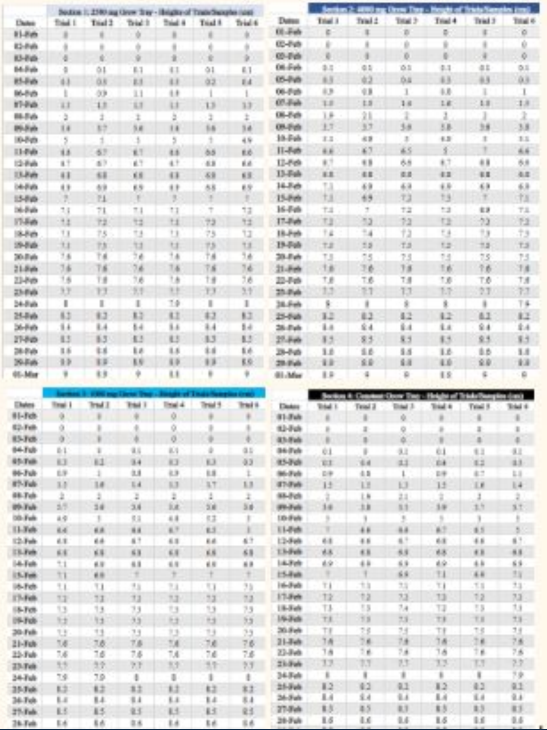
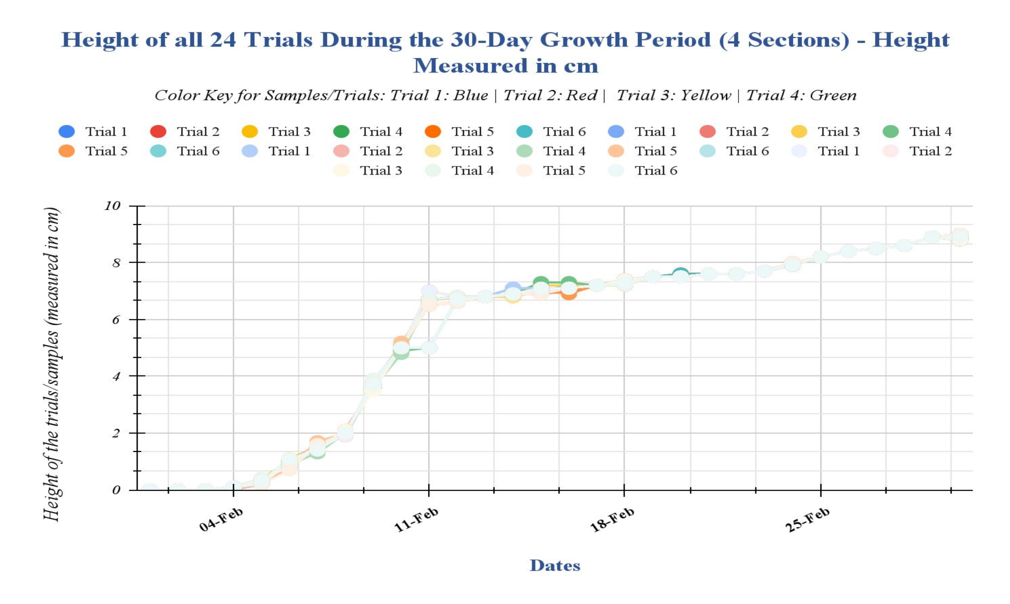
TABLE + GRAPH 4 - #4.1 - 4.2 = Root Length Data
TABLE + GRAPH #5 = R.W.C. Data

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





#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

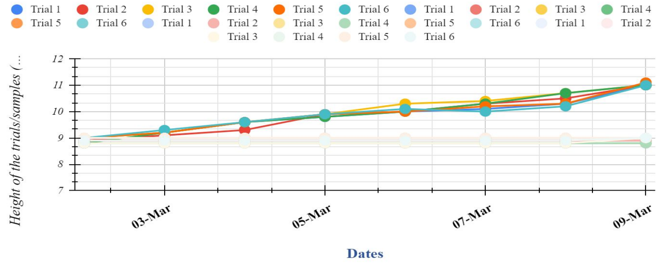
	Section 2: 4000 mg Grow Tray - Height of Trials/Samples (cm)					
Dates	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
02-Mar	9	8.9	9	8.8	9	9
03-Mar	9	8.9	9	8.8	9	9
04-Mar	9	8.9	9	8.8	9	9
05-Mar	9	8.9	9	8.8	9	9
06-Mar	9	8.9	9	8.8	9	9
07-Mar	9	8.9	9	8.8	9	9
08-Mar	9	8.9	9	8.8	9	9
09-Mar	9	8.9	9	8.8	9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

Height of all 24 Trials/Samples During the 8-Day Drought Period - Height measured in cm

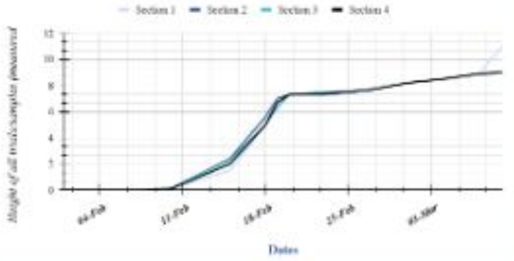
Color Key for Samples/Trials: Trial 1: Blue | Trial 2: Red | Trial 3: Yellow | Trial 4: Green



#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

Average Height of 4 Trials During the 8-Day Drought Period and 30-Day Growth Period



#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)

Dates	Section 1: 2000 mg Grow Tray - Height of Trials/Samples (cm)								
	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	0.2	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	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7	2	50%
16-Feb	7.5	7.5	7.5	7.5	7.5	7.5	7.5	0.5	4%
19-Feb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.5	0.2	2%
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	9.5	0.6	6%
09-Mar	11	11	11	11	11.1	11	11	10.7	90%

Dates	Section 2: 4000 mg Grow Tray - Height of Trials/Samples (cm)								
	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	1.5	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	50%
15-Feb	7.1	6.9	7.2	7.1	7	7.1	7.1	2.1	42%
16-Feb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.3	0.2	3%
19-Feb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	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%

Dates	Section 3: 1000 mg Grow Tray - Height of Trials/Samples (cm)								
	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	1.5	1.7	1.5	1.5	1.4	7%
10-Feb	4.9	5	5.1	5	5.1	5	5	3.5	43%
15-Feb	7.1	6.9	7	7	7	7	7	2	40%
18-Feb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.2	0.2	3%
19-Feb	7.5	7.5	7.5	7.5	7.5	7.5	7.5	0.3	3%
20-Feb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	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%

Dates	Section 4: Constant Grow Tray - Height of Trials/Samples (cm)								
	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%

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

Dates	Section 1: 2000 mg Grow Tray - Leaf Count					
	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

Dates	Section 2: 4000 mg Grow Tray - Leaf Count					
	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

Dates	Section 3: 1000 mg Grow Tray - Leaf Count					
	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

Dates	Section 4: Constant Grow Tray - Leaf Count					
	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	3	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

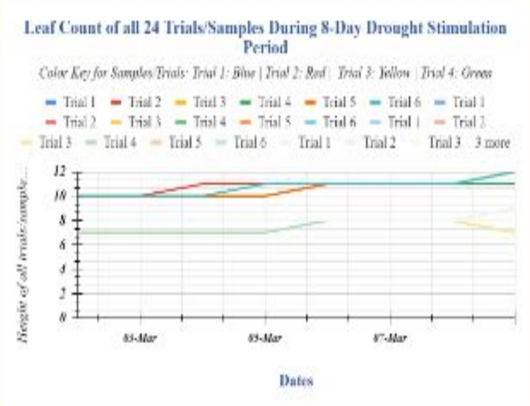
#2.2: Leaf Count of all 24 Trials (4 Sections) During the 8-Day Drought Period (4 Sections) - Height in cm

	Section 1: 1500 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

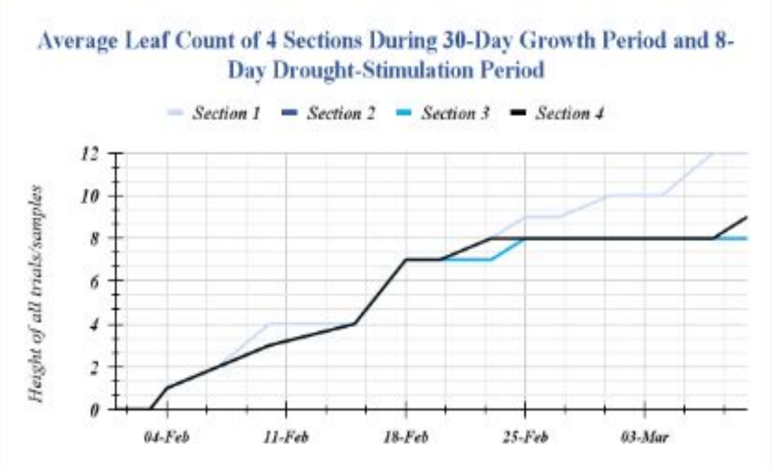
	Section 3: 1000 mg Grow Tray - Height of Trials/Samples (cm)					
Dates	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
02-Mar	7	8	7	7	8	8
03-Mar	7	8	7	7	8	8
04-Mar	7	8	7	7	8	8
05-Mar	7	8	7	7	8	8
06-Mar	8	8	8	8	8	8
07-Mar	8	8	8	8	8	8
08-Mar	8	8	8	8	8	8
09-Mar	8	8	7	9	8	8

	Section 4: Control 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



Leaf Count During the 30-Day Growth Period and 8-Day Drought Stimulation Period (4 Sections)

	Section 1: 3500 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	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: 5000 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	3	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	3	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	8	8	8	0	0%

#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: 3500 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	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%

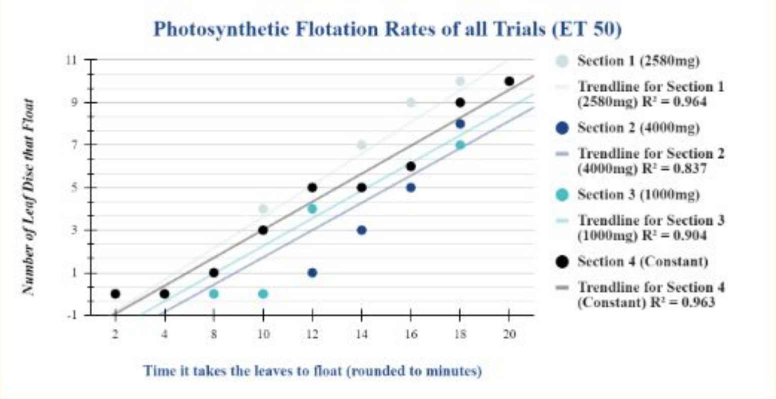
	Section 2: 4000 mg Grow Tray - Height of Trials/Samples (cm)								
Dates	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Average	Change in Length	% Change in Length
01-Feb	0	0	0	0	0	0	0	0	0%
03-Feb	0	0	0	0	0	0	0	0	0%
04-Feb	1	1	1	1	1	1	1	1	0%
07-Feb	2	2	2	2	2	2	2	1	0%
10-Feb	3	3	2	3	3	3	3	1	0%
15-Feb	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: 5000 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	3	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	3	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%

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

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

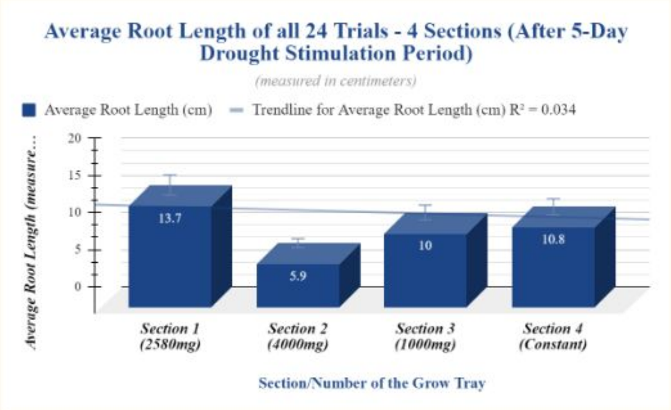


Root Length of all 24 Trials (4 Sections) - Extracted After 5-Day Drought Period + 20-Day Growth Period (Height in centimeters) - No Graph Could be Made Due to Error with Google Sheets

	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 11	Tria 12	Trial 3	Tria 14	Trial 5	Trial 6	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Tria 16
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

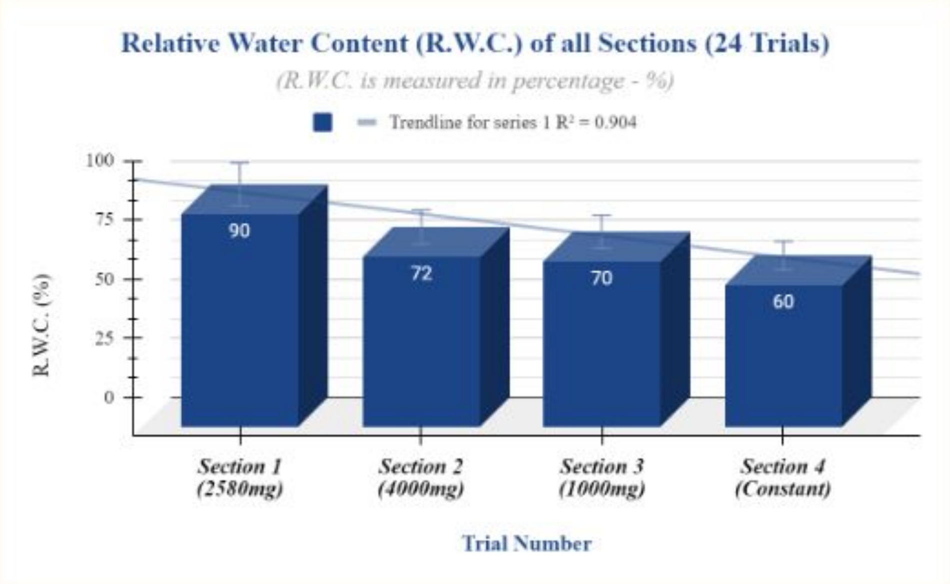
Average Root Length of Sections (Measured in centimetres)

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



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



Analysis

- During the 30-day growth period, all canola sections showed similar growth rates, with consistent pigment, leaf count (average of 9), and final height (average of 9 cm), indicating effective control of variables.
- Throughout the 8-day drought simulation period, after hydrogel application on day 1, no significant differences were observed in average height and leaf count. Primary results were internally assessed via R.W.C. and photosynthetic flotation.
- Minimal progress was observed during the drought simulation period, with average height increasing by about 0.1 cm and leaf count by 1.
- Average heights across sections were 11, 8, 8, and 9 cm, and average leaf counts were 12, 8, 8, and 9, respectively.
- R.W.C. and photosynthetic flotation revealed notable differences, indicating varying levels of hydrogel resistance to drought.
- R.W.C. percentages ranged from 90% to 60%, and photosynthetic flotation times ranged from 12 to 16 minutes across sections.
- Results suggest that section effectiveness ranged from least to most effective: Section 4, Section 3, Section 2, and Section 1.
- Section 1 displayed higher R.W.C. and increased average leaf count and height despite drought conditions, supporting the hypothesis that an optimal hydrogel amount aids water uptake during drought, as evidenced by photosynthetic flotation and R.W.C. metrics.

Results (More Detailed in Logbook)

- Canola seedlings showed no visible difference under drought conditions, but metrics indicated varied hydrogel efficacy.

Section 1 (2850 mg):

- Photosynthetic ET 50: 12 minutes 26 seconds (2% faster than average for canola)
- Average height: 11 cm
- Average leaf count: 12 leaves
- Average root length: 13.7 cm
- Relative Water Content (R.W.C.): 90% (0.5% higher than canola average)

Section 2 (4000 mg):

- Photosynthetic ET 50: Around 14 minutes (Second-highest)
- Average height: 8 cm
- Average leaf count: 8 leaves
- Average root length: 5.9 cm
- R.W.C.: 72% (27% lower than canola average)

Section 3 (1000 mg):

- Photosynthetic ET 50: Around 16 minutes (Third-highest)
- Average height: 8 cm
- Average leaf count: 8 leaves
- Average root length: 10 cm
- R.W.C.: 70% (19% lower than canola average)

Section 4 (No Hydrogel):

- Photosynthetic ET 50: Around 16 minutes (Fourth-highest)
- Average height: 9 cm
- Average leaf count: 9 leaves
- Average root length: 10.8 cm
- R.W.C.: 60% (29% lower than canola average)

Conclusion

Hydrogel application significantly influences canola plant drought resistance.

- Optimal amount: 2580 mg natural-polymer hydrogel.
- Key metrics: R.W.C. (90%), average height (11 cm), average leaf count (12 leaves), average root length (13.7 cm), and photosynthetic flotation (12 mins 26 secs).
- Other sections show lower metrics, indicating poorer health.
- Section 1 exhibits notable increase in R.W.C., leaf count, and height.
- Comparison: Section 4 < Section 3 < Section 2 < Section 1.
- Conclusion: Optimal hydrogel amount for enhancing canola plant drought resistance is 2580 mg.

Future Plans/Extension:

- **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

- **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

How Can I Improve My Experiment?

1. **Used a more sophisticated method to test water potential, RWC, and the rate of photosynthesis** *(to enhance data collection) - use actual meters (can't due to accumulating to cost of nearly $5000)*
2. **Used a growth chamber** *(to minimize human error)*
3. **Formatted all the observations in a graph for all the samples** *(couldn't due to there being 60 samples which couldn't fit all on a graph in a readable manner)*
4. **Have more metrics to measure drought resistance** *(to enhance data)*
5. **Set experiment in various climates** - to see how hydrogel works in drought centred season like summer.

Applications/Extensions

1. Water Storage and Delayed Versioning
2. Seed Coatings
3. Drought-responsive watering frameworks
4. Study on Hydrogel Formulations
5. Practical Trials and Evaluation
6. Affiliation with Agricultural Extension Service

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. **Incorrect application of hydrogel:** application of the hydrogel was meant to be done 3 cm below topsoil line with a ruler.

3. **Machine error** - pH, EC, or temperature meter 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 a measurement

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

5. **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.

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

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- I am indebted to my Science teacher/Science Fair coordinator, Mrs. Aulakh, for providing me with unmatched support and guidance in the various aspects of this project

- Lastly, I would like to thank Khalsa School Calgary for letting a school-wide Science Fair to take place in the first place.

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Thank You for Listening and I Look Forward to Meeting Everyone at the In-Person Fair!