

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?



By: Japp Kaur Gill 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/10.1007/978-3-030-7 6523-1 5-1



The hydrogels added to the soil absorb huge amount of water to improve the soil properties and



Soil amendment, water retention, sustained release, delivery systems acheived by hydrogels

 Fig. 1 — Application of hydrogel to soil/roots of a mature tree to give run-down of what goes on below the soil. Available: <u>https://link.springer.com/referenceworkentry/10.1007/978-3-030-76523</u> -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 <i>(this was backed up by research which can be seen in the hypothesis)</i> .	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: <u>https://www.producer.com/news/flash-droughts-can-pos</u> <u>e-risk-to-crop-production/</u>

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.

	4 TYPES OF	- DROUGH	T
AGRICULTURAL	SOCIOECONOMIC		
DROUGHT	DROUGHT	DROUGHT	DROUGHT

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



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
рН	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 <i>(Rate</i> of Photosynthesis)	"In the leaf-disk assay, all of the components necessary for photosynthesis are present" (<i>Photosynthetic Floatation</i> , 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).
	Here Here	
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.



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 cm³ (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 cm³ 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: "ET50")
- 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 Required for Growing Canola:	<u>Materials Required to Measure Photosynthetic</u>
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 <u>Materials Required to Measure Leaf Relative Water Content:</u>	Flotation: Flotation: Flotation: 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)
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	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°C 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



Section 3: 0.3 cm

Section 4 (Constant): 0.3 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.



Section 1 (2850 mg)

Section 2 (4000 mg)

Section 3 (1000 mg)

Section 4 (Constant)

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) 0

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



R.W.C. Weight Measurements of Leaves





R.W.C. Calculations/Results

RNC Calculations Section 2 Dry Weight = 59 Dry weight = Ing ZWC Calculation Section 1 (Recommendally urgid weight = 30 mg Turgid weight = 17 mg Freshweight = 23mg Avent) RWC (16) = (fresh weight - dry weight) x100 Lorgid weight - dry weight) x100 RoWo C - (Fresh reight - dry reight) x 100 (%) bryidneight - dry reight) x 100 $\frac{PWC}{(2^{\prime}o)} = \left(\frac{23 \text{ mg} - 5 \text{ gng}}{30 \text{ mg} - 5 \text{ mg}}\right) \times 100$ $\frac{2WC}{l^{g_0}} = \frac{16 \text{ mg} - 7 \text{ mg}}{17 \text{ mg} - 7 \text{ mg}} \times 100$ $\frac{RWC}{(\infty)} = \left(\frac{18 \text{ mg}}{25 \text{ mg}}\right) \times 100$ RWC = 0.72 mg x100 LWG = 0.8 mg x100 - Comparison RWC = 72%| KWC = 90% Average RW.C of cancia = 84,5-89.6% (- Comparison RW.C of trial 2 = 72% Average RWC of Carola = 84.5-89.6% [facing 5 days of drought) (72%< 84-5-89.6%) RWC of Trial = 90% 90% × 84.5-89.6%

Pry Weight = 8 mg Tigid weight = 28 mg ish Weight = 22 mg ZWC Calculations Section 3 PWC = (fresh neight - dry neight) × 100 (%) = (trigid neight - dry neight) × 100 $\frac{RWC}{(50)} = \left(\frac{22 \text{ mg} - 8 \text{ mg}}{26 \text{ mg} - 8 \text{ mg}}\right) \times 100$ $RWC = \left(\frac{14 \text{ mg}}{20 \text{ mg}}\right) \pm 100$ Comparison $\frac{RWC}{(96)} = 0.7 \text{mg} \times 100$ RWC = 70% Averge RWC of canola = 84.5 - 89.6% RWC of Trial 3 = 70% 70% < 84.5-89.6%

Dryweight = 8gmg shweight = 30m ZWC Calculations Section 4 your aright = 30-(Constant) PWC = (tresh reight - dry neight) × 100 (%) turgie neight - dry neight) × 100 $\frac{2WC}{(%)} = \left(\frac{23 m_{g} - 8 m_{g}}{30 m_{g} - 8 m_{g}}\right) \times 100$ $\frac{PWG}{(90)} = \left(\frac{13 \text{ mg}}{22 \text{ mg}}\right) \times 100$ *k*WC ≈ 0.6 mg ×100 (%) (%) = 60 % (omparison Average PWC of Canala = 84.5-89.6% ZWC of Trial 4 = 60 % 60% < 84.5 - 89.6%

Root Length of 4 Sections (24 Trials)

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 3 (1000 mg) - Average = 10 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 4 (Constant) - Average = 10.8 cm



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 4 - #5 = R.W.C. Data

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

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

-	Sector	1,2580.00	Geore Thay	- Ibigite of	Trainfluor	des table	Dates	Sector Sector	Total 4	D	Total A	Trial I	tes (res)
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04.040	<u> </u>	01	- 6.1	43	- 01	6.1	00.040			0.5	- 24		9.5
0.690		0.8	- 13	4.1	92	84	10-948			0.4			- 9.9
86-740		-09	11	1.0		1	00-710	1.2	- 12	1	- 1.0		
11440.	-11	1.1	-1.1	11	1.5	3.9	47-24b	3.8	1.1	3.6	1.8	1.1	-1.8
85.6	- 2	2	1	2	- 2	2	06-049	18.1		- A	- A		2.
19-546	1.6	87	3.6	14	5.6	3.6	05-250	17	3.7	3.8	3.8.	- 28	-34
10-545	5	1.1	- 5	5	. 1	4.9	38-Fab	8.1	6.8		4.2	- 1	15
11440	8.8	67	8.1	8.8	0.5	6.0	11-848	4.6	- 67	6.5	1		6.6
274	1.7	1.67	6.7	4.7	-68	6.6	12-649	8.7	- 13	6.5	87.		6.8
0.84	11	54	6.8	43	68	63.	33-Fab	88.	1.1	8.8	4.2		4.5
04-549	4.9	. 69	6.9	1.7	5.8	6.9	14-84		69	6.9	4.8	69	6.9
15-840	2	15	1		1.1		15-Print	+.t.	69	.73	13	1.1	14
06-546	.14	71	7.1	11		12	36-548	74 -	7	7.2	1.2	6.8	7,1
150	12	72	12	ta	72	12	17-846	11	12	7.2	12	22	12
880	11	7.5	1.8	1.8	75	12	18-849	7.4	14	12	1.4	1.9	.73
5-546	1.1	1.11	.11	11.	75	12	19-548	1.7.8	2.5	1.5	12	1.15	1.5
00.046	7.6	1.7.4	2.6	7.6	7.6	3.6	39-Feb	7.5	7.5	7.5	7.6	7.5	7.5
1.64	14	1174	26	74	7.6	16	21.844	14	36	7.6	26	26	7.4
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28.846 15.846 15.Mar	1.6 3.9 9	18 18 19	1.0 1.0 9	13 19 11	14 12 1	8.6 8.0 9	23-745 23-746 01-Mar	11 12 17	8.0 8.0 4	8.5 8.8 0	1.6 4.0 1.9	8.0 9.0 5	1.8 8.8 0
58.0x0 59.0x6 16-Mar	1.5 3.9 9	18 13 13	1.0 3.0 9	U U U	14 13 1	8.6 8.0 9	23-745 23-746 01-Mar	13 13 13	1.0 3.0 4	1.5 1.0 0	1.5 1.0 1.2	8.0 9.0 5	1.4 9.2 0
26 Evo 26 Evo 16 Mar Dates	1.5 3.2 9 Normal Time 1	14 13 13 74/1	1.0 1.0 9 7 7 7 7 7 7	13 12 11 1044	8.6 83 9 7001	8.6 8.0 9 70015	29-Fub 20-Fub 01-Mar Dates	1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0	5.6 5.0 4 Tend 3	8.5 8.0 9 70473	1.5 1.0 1.2 1.2	8.0 9.0 5 Teni 5	1.4 9.3 0 10010
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870 826 5.Mr 1.470 1.470 5.760	8.6 89 9 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	44 19 19 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	14 14 14 14 14 14 14 14 14 14	44 49 40 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	44 99 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	14 14 14 14 14 14 14 14 14 14	23-740 23-840 61-Mar 11-244 12	14 14 14 14 14 14 14 14 14 14	8.6 8.0 9 7 7 10013 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	8.8 8.9 9 9 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	1.6 8.6 8.6 1.5 1.6 1.6 1.6 1.6 1.6 1.6 1.6 1.6	8.8 8.9 6 7mil 3 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	144 9 9 9 10 10 14 9 9 9 10 14 9 15 14 9 15 14 9 15 15 15 15 15 15 15 15 15 15 15 15 15
870 8266 5.Mar 1. Mar 1. Mar 1	14 39 9 10 10 10 10 10 10 10 10 10 10	444 183 19 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	14 14 14 14 14 14 14 14 14 14	43 49 40 40 40 40 40 40 40 40 40 40 40 40 40	44 19 10 10 10 10 10 10 10 10 10 10	84 88 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	23-740 23-240 01-340 0-2400 0-240 0-240000000000	149 149 149 149 149 149 149 149 149 149	8.6 8.0 9 7 7 10 12 8 9 9 8 4 13 13 14 14 15 15 15 15 15 15 15 15 15 15 15 15 15	4.3 4.4 9 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	1.6 1.6 1.6 1.6 1.6 1.6 1.6 1.7 1.6 1.7 1.6 1.7 1.7 1.7 1.7 1.7 1.7 1.7 1.7	8.6 9.0 9 Total 5 4 1 1 1 1 1 1 1 1 1 1 1 1 1	1.4 m 1.4 m 1.
21700 2028/6 1-Mar 1-100 2-1000 2-1100 2-1000 2-1000 2-1000 2-1000 2-10000000000	8.6 89 9 10000 100 100 100 100 100 100 100 10	643 183 193 194 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	44 14 14 14 14 14 14 14 14 14	13 19 10 10 10 10 10 10 10 10 10 10	44 88 9 7004 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	84 86 9 10014 9 9 0 0 0 1 10 2 14 9 0 0 1 0 0 1 10 2 14 9 0 10 10 10 10 10 10 10 10 10 10 10 10 1	23-740 28-240 28-240 28-240 23-240 20	12 12 12 12 12 12 12 12 12 12 12 12 12 1	44 49 7 mild 4 5 4 7 mild 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	843 643 6 7 7 7 7 8 7 8 8 8 8 8 7 7 7 8 7 8 7 8	8.8 8.8 8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	80 80 50 50 50 50 50 50 50 50 50 5	1.4 9.8 9.4 1.4 9.4 9.4 9.4 9.4 9.4 9.4 9.4 9.4 9.4 9
2010 29266 11.Mar 2016 11.100 10.1000 10.1000 10.1000 10.1000 10.100000000	14 39 9 10 10 10 10 10 10 10 10 10 10	43 13 13 14 14 14 14 14 14 14 14 14 14	14 19 10 10 10 10 10 10 10 10 10 10	13 14 15 16 16 16 16 16 16 16 16 16 16	44 99 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	84 86 9 10014 9 9 4 1022 1022 1022 1022 1022 1022 1022 10	23-740 28.740 28.740 23.7730 23.7730 27.7400	13 13 13 14 14 14 14 14 14 14 14 14 14 14 14 14	44 49 40 70ml3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	43 43 6 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	8.6 8.6 9.6 9.6 9.6 9.6 9.7 9.6 9.7 9.6 9.7 9.7 9.7 9.7 9.7 9.7 9.7 9.7 9.7 9.7	80 80 80 80 80 80 80 80 80 80 80 80 80 8	1.4 4 8 8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9

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





Dates

#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)						Section	2: 4000 mg	Grow Tray	- Height of	Trials/Samp	les (cm)	
Dates	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Dates	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
02-Mar	9	8.9	9	8.8	9	9	02-Mar	9	8.9	9	8.8	9	9
03-Mar	9.2	9.1	9.2	9.2	9.2	9.3	03-Mar	9	8.9	9	8.8	9	9
04-Mar	9.6	9.3	9.6	9.6	9.6	9.6	04-Mar	9	8.9	9	8.8	9	9
05-Mar	9.8	9.9	9.9	9.8	9.9	9.9	05-Mar	9	8.9	9	8.8	9	9
06-Mar	10	10	10.3	10	10	10.1	06-Mar	9	8.9	9	8.8	9	9
07-Mar	10.1	10.3	10.4	10.3	10.2	10	07-Mar	9	8.9	9	8.8	9	9
08-Mar	10.3	10.5	10.7	10.7	10.3	10.2	08-Mar	9	8.9	9	8.8	9	9
09-Mar	11	11	11	11	11.1	11	09-Mar	9	8.9	9	8.8	9	9

Dates	Section	3: 1000 mg	Grow Tray	- Height of	Trials/Samp	ies (cm)		Section	4: Constant	Grow Tray	- Heights of	Trials/Samp	les (cm)
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Dates	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
02-Mar	9	8.9	9	8.8	9	9	02-Mar	9	9	8.8	9	9	8.9
03-Mar	9	8.9	9	8.8	9	9	03-Mar	9	9	8.8	9	9	8.9
04-Mar	9	8.9	9	8.8	9	9	04-Mar	9	9	8.8	9	9	8.9
05-Mar	9	8.9	9	8.8	9	9	05-Mar	9	9	8.8	9	9	8.9
06-Mar	9	8.9	9	8.8	9	9	06-Mar	9	9	8.8	9	9	8.9
07-Mar	9	8.9	9	8.8	.9	9	07-Mar	9	9	8.8	9	9	8.9
08-Mar	9	8.9	9	8.8	9	9	08-Mar	9	9	8.8	9	9	8.9
09-Mar	0	8.0	0	8.8	0	0	09-Mar	9	9	9	9	9	9



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

#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 (2	4 Trials) - Height measu	red 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	p	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)

	Name of Street, Street			Sect	les 2: 2559 mg liv	ow long - Molghin	of State Scopler 2	(m)	
Dates	Tried 1	Tried 2	Trial 3	Eriol 4	Trul 5	Tirial 6	Arerage	Change in Length	% Change in Leight
01-Feb	1.0		0	4	0	0	Ď	0	125
05 Ech		1	- K.		0	0	0	0	174
Ob Exh		0.3	0.1	0.1	0.5	4.1	E.1	E.I.	191
UT Feb	1.8	3.5	1.6	10	3.3	8.5	1.5	1.4	75
10.Fab	31		1		3	4.0	. 1		495
13 545		(4	1		14	1.	· 7	1	80%
10-Feb	7.8	7.8	7.8	7.8	7.8	12	2.5	A1	4%
19 1 cb	.7.9	3.7	2.9	1.0	51	12	12	0.2	2%
20 Feb	26	7.6	26		7.0	7.4	1:5 · · · ·	n+	195
23.548	2.0	3.7	101	3.2	357	8.2	3.8	0.1	25
25-Feb	8.2	8.2	2.8	8.2	8.5	8.2	1.5	0.1	194
27.849	8.7	8.5	8.1	8.6	8.2	8.3	1.0	0.1	175
01-Mar	9	8.9	9	6.8		9	8.9	0.4	216
94.58er	9.6	9.3	9.6	.24	5.5	2.6	5.5	0.4	174
89.3der	13	11	33	11	18.0	11	11	19.7	90%
		11				-	-	100	NO.235
Dates	Total I	Trial 1	Trial 3	Trial 4	Trial 5	Trial d	Arecaar	Change in Length	Vi Change in Length
01.Pub		0		0		0	0	0	0%
85 Feb		0.		. 0	8	0	0	0.1	044
94 Feb	8.1	4.1		41	63	-0.1	0.1	0.1	8%
95-Feb	1.5	2.3	1.8	3.4	1.5	1.1	1.5	1.4	2%
10.548	31	4.9		4.9		5.1		1.5	42%
13-Feb	7.6	6.9	7.2	13	7	14	1.1	21	-42%
18.Fub	1.4	2.4	12	- 12	3.0	1.0	7.1	0.7	1%
Lo Feb	13	1.4	13	53	13	14	7.5	0.2	3%
29-Feb	7.5	7.7	7.1	7.8	11	2.5	13	0	0%
25-Feb	13	2.7	- 17	3.2	3.3	2.7	1.1	0.2	3%
28.848	8.2	8.2	8.3	8.2	8.3	8.2	8.2	0.3	8%
37 846	12	0.5	8.3	8.7	8.5	8.5	8.7	0.5	446
for Mart	-	5.0		4.4		4			100
en Mar		2.9	2	2.2				0	01s
				Sect	tes 5, 1800 mg Ge	ow True - Height	of Trials/Storgive 1		
Detes	Trial I	Trial 2	Tread 2	Trial 4	Trial 6	Trial 6	Average	Change in Longth	No Change in Long
01-Eob	ú	0		0.0	0	41		0	0%
45-EVb					0		1	0	0%
64.216	6.1		0.1	0.1	0	1.1	0.3	0.0	0%
47-Feb		1.4	14	1.2	1.7	1.0	1.5	14	75
10 000	19		111	4.8	4.7		5	2.5	12%
16-Feb	15	10					,	2	435
12 046	14	11	11			19	2.2	8.3	12
10.Fub		7.6				7.6	24	62	24
St. Date		~		14			1.5	11	1774
TR. Nak			**						10
AT DO					1.1				
10 100	2.2	1.2	1.2		4.2	2.2		6.5	075
2:-140	8.5	8.5	8.5	8.5	8.5	1.7	8.5	83	*1
er Mar		1.9	5	5.5	9	9	1.5	8.5	0%
04-Mar	9	1.9	5	8.8	9			6.1	1%
49. Mar		8.9		8.5			Section 1	8.1	174
1.1.1				Kart	ine II: Constant Co	on Day Hught	of Tetals Samples (r		
Dates	Trial 1	Trial 3	Trial 5	Trial 4	Total 5	Trial 6	Arerage	Change in Longth	vs Change in Longth
10 775									(P)
CA Reb							10.1	1.4	
01.546				11	21	1.1	1.5	14	145
SV-2.95					10		8.2	1.7	

42

12

3.1

2

0.9

73 75 30%

0271

-014

3%

kb-Feb

18.946

15 715

25.746

20-7+6

49

74.

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

		Set	in 1 200 og D	wither-last	int i					in 1 million fo	in Ter Lett	-	
Dem	2441	2002	Triald	Dista	Tradif	THEF	Dem	Tred 1	2041	Tracil	Disk	Trait	Dials
6.74	0	0	1		1	1	11-546		0	0	1		0
0.94			-				12-846			- H-			
0.74							0.548						1.0
61748	-	1		1		_	14.04		1				
0.74	- A.	1		-			15.518						
10.716		- 3	4		1	1	10.710		_		-		
0.00	100						17-010			-			
10.710			-			-	10.746			1	1		
11.54	100					1.0	10.04				+		
1.14	5	1		-		100	11.54	-					
11.644	1		1.		1	-	11.040						1
21.74						1	11.04						1.4
ball to be		4				1	14.549		4				
25-74	4	4	4	4	4	4	15-740	4	4	4	4		
25-Feb	4		1	1			18-Feb	1	1				1
25.84	1	*	1			1	17-548		1	1		1	. 8
30.716		. 1	9.5	. 1	9.5	1	18-0 mb				9.1		
35.846	+	1	÷	+	÷	+	19-04	. 1				. 1	
25.718	÷	. †		+	9.		70.8vb					9	
2.54	7	1	7.	1	1	1	21.048	1		- <u>*</u>	÷.	1	1
27.64	+	. *	÷	. 8	8		22.648	. 1	1	. T.			1.1
25-846	1			- 1	1	1	25-54b	. 1	1	7	T.:	2	<u></u>
31.718	1			1	1	1	24-848		1			. 7	
25-748	1	1	7.5	1	1	1	22-248			1.1		0.0	102
25.718	1	1		1		-	10.040	_		_			_
2506		102					27038						
10.010						-	19.54			-			
10.464					-		Cl. Max						1
Contra .													
			in 7 life of G	no Tro-Laf	-	_	1000		let	tes 4 Constant G	ow They-Look	and in the second	
Dete	THU1	241	DMJ	2644	Trail	764	Dens	2141	3443	THE	THE	Trial #	Trail #
11.74		1		1			11745		4				
12-248			1	1	8	1	43-Ex6	1	. 0	0	1	1	1
0.74		1	1	1	1	1	43.8wb	.0			0	-1	4
10-740	1	- 1	1.	1	1	- 1	04-040	1	. 6	1	1.	- 1	1
1924	1	1	1	1	1	1	01.040	1	1	1		1	1
16748	2 -	2	1	- 3	2.	2	04-T+b	- 2	- 2	1	2	- 1	2
1770	2	2	1	1	2	- 2	17746	1	2	-1	2	-1	1
1914	2	+	1	1	1	2	16740	- 2	3	1	2	1	3
1970	2	2	1	1	1	2	19.745	3	- 2	3	3.	\$	3
20-548	2.	1	1	1	3	3	18-846	1	3	1	3	1	1
13.746	1.	- 1	2	1	2	9	1174)	1			1
12-2-48	3	- 2	1	- 3	3	2	13-Feb	3		3	3	1	- 3
13-74		4			6	4	Urb				6		
14/14		+					14-746		+	4	4	6	4
1574		- 2	÷	- 1	4	4	1684						. 6
26-246	1	1		1	1	1	Lti-Pala	1	3			1	1
1756	1	1				1	1774		1	*			
25-246	+		+	. 1	.+.		18-746	1	1: 1:	±	+	1	
19.74							UF-Pub	1			2	. +	
10-248	7			. 1	-7		28-Teb	÷	- 7	T.	2		2
370	+	. *	+			0.901	23.646	1	1	۹.			
11-54		4			+		23-246		1	1			1
35.748	+	1	τ.				23.646		1	1			1
10-548	9	4				9	24740	. 1	1	1			1
		1			-	-	14.0.0						

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

Triel1

Dial1

		Section 1:150	il my Grow Tray-	Heights of Trisk	Samples (cm)		
Dutes	Trial I	Trial 2	Trial 3	Trali	Trial 5	Trialó	Datas
02-Mar	11	10	II	10	10	30	12-Mar
33-Mar	10	10	IE	10	10	30	13-Mar
M-Mar	10	11	10	10	10	00	H4-Mar
05-Mar	10	11	11	10	10	11	15-Mar
96-3/ar	11	11	11	11	п	11	16-Mar
07-Mar	15	11	11	11	11	11	17-Mar
88-Mar	10	11	11	31	11	11	18-Mar
99-1far	12	12	11	51	12	12	19-Mar

	12-Mar	7	8	7	1	1	8	
	13-Mar	7	8	7		1	5	
	14-Mar	1	8	7	7	1	8	
	15-Mar	7	8	. T.	2	1	8	
	16-Mar	8	8	8	1	1	5	
	17-Mar	8	8	8	1	1	5	
	18-Mar	8	8	8	1	1	8	
	19-Mar	8	8	7	P	1	\$	
4	*********		Section & Co	andhail Gren Tray-	lieight of Triab	Samples (cm)		1
	Dates	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	
	02-Mar	1	8	8	8	1	1	
	03 Mar	4	8	8	8	1	1	
	04 Mar	1	5	8	8	I	1	

Section 2: 4004 mg Crow Truy - Height of Trials/Samples (cm)

Trial 3 Trial 4

Trial 5

Trial 6

		Section 3: 10	10 mg Grow Tray	- Height of Trink	Samples (cm)		Dates	Trial I
Dates	7601	7662	Trial 3	Trial (Trial 5	Trial 6	43.Mar	1
62-Mar	7	4	1	9	1	1	13 Mar	1
63-Mar		5	1	7	\$	1	A4 Mar	1
(4-Mar	. 7	1	1	1	1	1	05 Mar	1
(6-Mar	.7	10 E	7		ł	1	AS Mar	1
(6-Mar	4	4	8	1	\$	- 1	d7.Mar	-
(7-Mar	1	£	8	8	8	- 1	ALMar.	
(5-Mar	1	1	1	1	1	1	33.3.far	
64-Mar	1	1.1	1.7	4	1	1	wan	•

Leaf Count of all 24 Trials/Samples During 8-Day Drought Stimulation Period

Color Key for Samples/Trials: Irial 1: Bine | Irial 2: Red | Irial 3: Yellow | Irial 4: Green



#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	It leight measured in on	
Dates	Section 1	Section 2	Section J	Section 4
01-Feb	6	û	Û	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	1
20-Feb	7	7	7	- T
23-Feb	\$	7	2	\$
25-Feb	9	8	8	1
27.Feb	9	8	3	8
01-Mar	10	8	3	ŝ
04-Mar	10	8	8	5
07.31ar	12	8	3	8
09-March	12	8	3	

Average Leaf Count of 4 Sections During 30-Day Growth Period and 8-Day Drought-Stimulation Period



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

					tion 1- HMM ang G	our Truy - Beight	of Trials Samples	(14)	
Dete:	Trial 1	Tread 2	Trail 2	THEFT	Total 9	Traid of	Assessor	Change in Longth	Ne Charge in Longita
01-E+b		. 1.	p.	0	0	1	.0	a.	0%
COLUMN TO A				0					0%
07.84	2	-	1			2.	2		244
10.0+6	2	2	1	3		3	8.6	1.1	23.78
10.04	4					1	4	E 4	10%
13.0+6									205
10.Puk	7	1	1	7		7.0			0*L
20.0vb		-		-					175. 1.00
27.246		50						1	10%
27.8vb		10		8					0%
H.Mar	10	50	30	10	10	10	50	1	17%
#4 Mar	10	st	30	28	10	10	30	2	20%
RP-Mail	- 12	12	- 11	11	12		-	1	20%
		1000		fare	in It all in a Gr	or Trop - Height o	of Trink-Sumpley (r	•	
flates.	Trist L	214M 2	THAT 2	Select #	Strat 5	Triste	Aurage	Charge in Longh	In Chings in Leigh
o Pres			0	0		.0	0		174- Mil
4 Feb	1		1	1	1	i.	1	1	P4+
7-Eab	2	- 1	3.	2	2	2	2	1	14.
5-Teb			2	- 3	3	- 5	3	1	2%
5-8-6		- 4				- 4	+	1	2%
B-F-b	3	- 1	1	. 7	3	- 2	<u> </u>	3	20%
8.94h	1			. 7	7	7	*		2%
1 P.4			-		1	- 7			27.0
1.548	7.			- 7		8		1	145
D-Evb	T	1	7	T		7	8	0	Pa
I-Mar	7	1	7	. 7	8.1		8	0	2%
4-Mer	¥.	1.1	1.	Y		2	8		2%
6-Mar	7		1	. 7		0		-0	0%
-		and the second		310	ice 3, 1000 vog 0	ner Toy - High	attent fingles)	Charles in Franklin	At Change in Longth
11.54	Tread I	in the second	mars	mut	mars	and a state of	areage.	C analysis of Compa	and the second s
43-Tab		0			0	0		0	0%
de Lab	1	10	0.1	4	1	1		1	174
#7-Feb	. 3	7	1	2	2	- 2	2	1	- 25
10.756	. 5	8.2	1	7		3	3	E	.10%
15-Teb	+	+ .	+	+	4		+	1	33%
12.116		7		7	.7	T	1	A	12%
in Feb	2			1		- F.:.		0	9%
15.5.6				7				0	144
28.816	7		T	+		×	1	E.	1/%
27-Feb	1	5	7	7.0	8		1	0	15.
01-Mar	2	8	1	3	0	5	1	0	25
fil.Mar	,	5	+	+ -		· 7		0	01.
09-Mar					я.	5		0.7	2%
-				Sect	ion & Countant D	new Tray - Beight	of Trido Samples (im)	
Dates .	Triel 1	Total 1	Trice a	Tests	Truit	Trials	Arrage	Change in Length	% Change in Length
10. Fak			-						100
04-8-4	1				1	1	1	1	05
07 Eck	2	1	2	2	2	7	1	12	174
16-T-b		1	2	1	1	5	1	100	1%
13 248	4			4	4		1	1	Una .
18.Pub	T	7	1	10	7	7	7		795.
15 8 ch		1.	Y.	1.1	1	- C -	1	0	0%
In-Feb	7	7	7	0 T	-	7	1		0%
10.048	*		1					10	0%
T. Kak									10%
H-Me				5	1		8	ě	0%
As blue					1.0			100210	
24-31M								0	0%
10 Mar	8		*		*	2	-	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)

				Servi	ini 1-25% org the	a Truy - Height	of Telsis Samples ((11)	
Dates	Trial L	Total 2	Trial 2	Trial #	Trial 2	Total #	-Anneage	Change in Longth	% Change in Longth
OB-Evels			0	.0	ù :				0%
03-Feb	+			0	4		0	8	0%
O4-Evb	1.0	1	1	1	1		1	1	01u
07.Feb		1	1		1	X	2	1	016
10-thub	2	3	3	3	2		3.3	2.9	21%
15-Fub	.4	4		. 4	4		4	0.1	54%
18 Peb	7	1	t.	1.1			7		23%
15-Fab		1			*				D*6
30 Feb	. 7	τ	÷.	1.2		2	y.,		014
23.Feb		9	T.	. 7				1	1/%
28.8vb		10		8				1	13%
27.8kb	1.0	10		8			9	4	0%
at-Mar	10	80	30	19	10	10	10	1	33%
94-Mir	10	11	30	10	10	3.0	30	2	204
#P Mar	13	1.2	33	11	13	12	12	2	20%

Sec. Sec.	10.000	CONTRACTOR IN	0.000	See	tes 7- ableb ang Ga	ros Trop - Beight	at Trisk famples (1. A. M.
Tistas	2 First &	Treed 2	Area 1.	# bendt	trial 6	Trial 6	Acorago	Charge in Longh	In Chings in Longik
RD Feb	- 0		4	0		0	0		24.
10-5-6	0	1	0	0	0	0	0	0	8%
04 F4h	1	1		1	- 1	1	1	1	19a
67-6-th	2	2	122	2.	2	2	2	1	0%
16-Feb		3		3	3	5	1	A	0%
12-2 th					. 1			1	074
15-Feb	2		2	9.	3	2.1	2	3	29%
38.846	T			2.	7	7	+	0	2%
28 Feb	T	1.	7	.7.1	1	2	T	9	25
23-8'sh	7	1		7	7	7	Ŧ		24
25-848	7		7	7		8		1. L	14%
27-Feb	1.1			7		7.		0	0%
03-Mar	7	1		T .		8.		0	15
04-Mer	e .	1		T		1	8	0	0%
09-Mar	7	1	+	7				0	0%

	10000	1.12.2024.00	Alexan	Sector Real	tim 5-1868 rag 10-	on Tory - Heigin	of Telebolic applies in		
. Ibeles	Tree 1	Trial I	Torial 5	Trud 4	Trial 5	Trial 6	Average	Change in Length	To Change in Length
01.Feb		4							17%
03-Teb	0	0	0		0.		e		25
04.3 ab	1.5	1	1	1	1	1	1.	1	0%
UT-Exb	1	- 2	2	2		2	2	1	216
16-Tab	3	3	7	. 3	8		2	1	50%6
15-Teb	4	+	+	-4	4.	+	4	1.	33%
12.040	÷.	10 P	± -		#15				73%
15-Peb		1.9		7	10	*		. 0	2%
20-Fab	9 A		R (1	7.				0	0%
23-Feb	7	-1	T .	1	7	2	3	0	0%
28.846	7	3	7 .	7		-8	8		14%
27-Feb	7		7	7	8	T		0	05
01-Mar	7.		7.	7		8	1	. 0	(Th
Bi-Mar	7		7	7		.7			-0%
109-54ar	9		10				- 5	0	2%

				See	en I. Constant D	ow Tray Bright	of Deblighting los ((m)	
Dates	Trial I	Total 5	Total 3	Total #	Trial f.	Trial 4	Aresage	Change in Leogth	% Change in Longt
05 Peb						10.	0	0	0%
03-848							0	0	0%
04-848	1	1	1	1		1	1	1	0%6
IT PAR	8	2	1		2	7	1	1	0%
10-2-th	3	.3	2	3	3	3	1	1	15
15-E+k	+	. 4	. 4	4.	4	. 4	-4	1	0%
15 Feb	9.1	1		1.	1.8	7.	T		75%
15.7+8	7	7	+	1	7	7	7	0	0%
28-8-6	7	. 7	P	3	2		. 9	0	0%
23 Pek	Ť	. 1		7	2	8		1	0%
28. Fak.	T	1						0	(7)

Photosynthetic Flotation .	late 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



Photosynthetic Flotation Rates of all Trials (ET 50)

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					ts of	4000 mg Grow Tray - Height of Trials/Samples					1000 mg Grow Tray - Height of Trials/Samples					Constant Grow Tray - Heights of Trials/Samples							
Frial Number	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Tria 11	Tria 12	Trial 3	Tria 14	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 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)

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

Average Root Length of all 24 Trials - 4 Sections (After 5-Day Drought Stimulation Period)

(measured in centimeters)





Section/Number of the Grow Tray

Time it takes the leaves to float (rounded to minutes)

R.W.C. (Relative Leaf Water Conten	t) 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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Thank You for Listening and I Look Forward to Meeting Everyone at the In-Person Fair!