

Plant growth And development

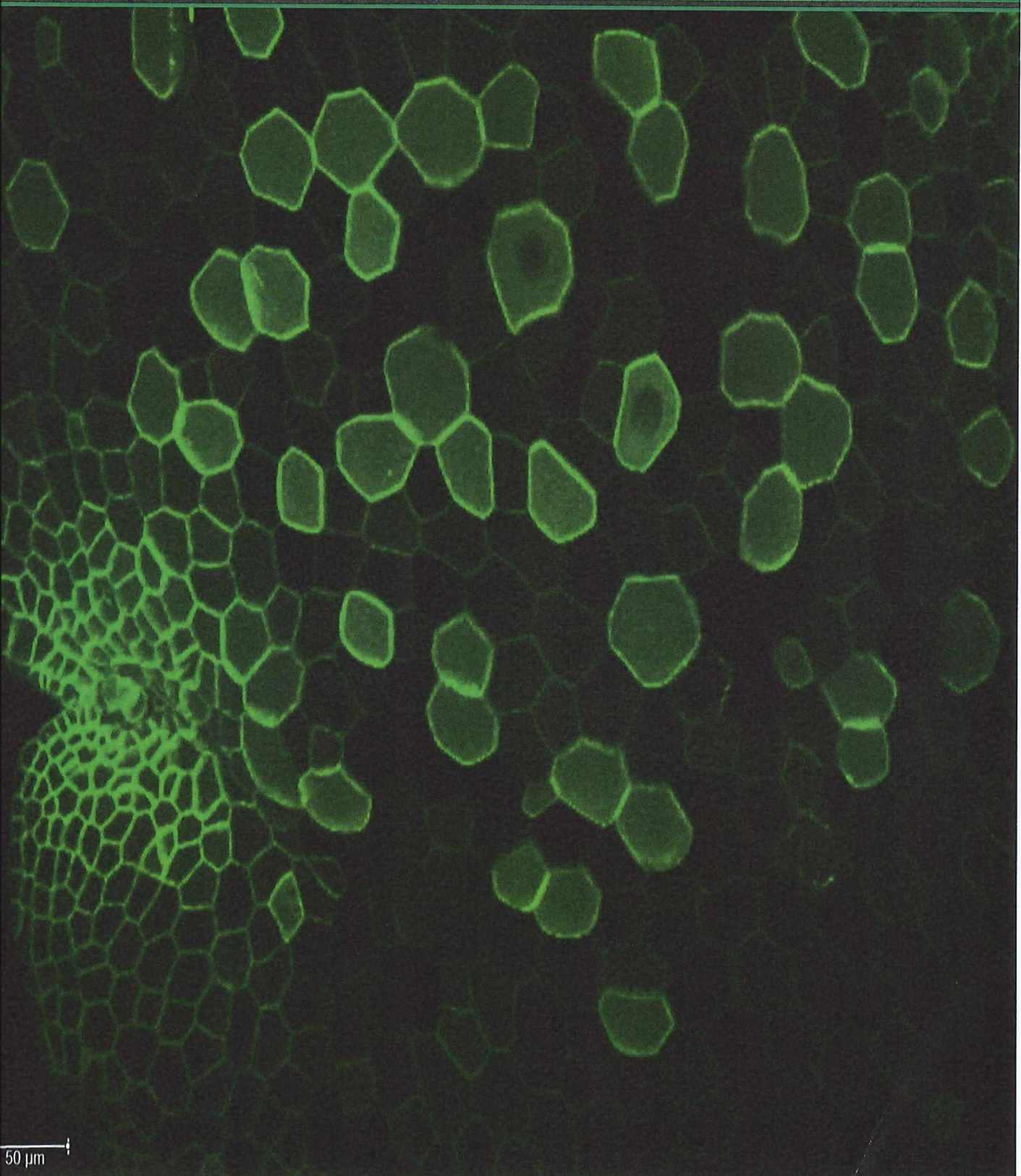


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Plant development and growth it is more sensitive to the environment than to animals

are very similar to animals they only differ by not having nerves or muscles so they cannot move or breathe. However, plants are considered to be more sensitive to environmental changes than animals as any change affects their growth and development instantly. They respond to changes in their surrounding environment by gradually altering their growth rate and their direction of it through changes in biological processes they undergo. (Staff, F. M. 2019, June 26)

Mostly stress that comes from the surrounding environment is the major cause that affects plant growth either directly or indirectly. Any unwanted change in the environment can have detrimental effects, such as having too little water can damage plants directly and in other cases it can affect plant immunity, making it harder to defend from disease or insect attack ultimately making it more susceptible.

It is really important to build a basic understanding of how the main environmental factors affect plant growth, which is: humidity, water, light, temperature, and nutrition. Nature and plants are the foundation of our lives and more than ever it's our duty to save and protect them as our lives are fully dependent on them. Therefore, having basic knowledge and understanding of how these environmental factors interact and what effects they have on plants and nature will enable us to manipulate plants to meet our needs, such as increasing food production. Additionally, with our deeper understanding, we will be able to identify those plant problems caused particularly by environmental stress and provide solutions.

Despite the fact that plants provide us with food and oxygen, they also have a lot of other benefits such as they help with mental health issues. Relaxation and meditation are also very important nowadays, they do help people to recover and feel better. Also, they do act as a form of inspiration for the artist. By all means, by the extinction of plants the whole chain will be affected and therefore it's important to educate and develop innovations that will protect and maintain the plants. (VanDerZanden, A. M. 2022, April 16).

Introduction and aims:

As mentioned in the abstract, first of all, to provide solutions and innovations to the problem, it should be acknowledged, researched, and understood, especially, the potential negative effects that it can have on plants. In other words, by starting from micro analysis we only then will be able to produce macro scale viable solutions. In my research, one of the environmental stresses that I will be looking at is the effect of temperature on plants. Particularly, what effects does the increased temperature have on the plant growth? In my investigation I will be using two model species *Arabidopsis* and *Marchantia*.

Literature review:

Model species are useful as a model for other plants because they usually have a small genome which makes it quicker to see any changes happening instantly, as the genome replication for cell division occurs faster and therefore less time-consuming. With a small genome, the co-regulation of multiple related genes is possible and fewer nutrients are required making it cost-effective. Additionally model species have relatively short life cycles, it's easier to obtain and maintain them in a laboratory and other experimental conditions and ultimately enables us to generate mutants to study certain traits or diseases. Therefore, by using model species they provide us with valuable insights into biological processes.

while provides info, this lacks info on the investigation + is more background research knowledge.

Plant growth models aim at describing the interaction between the growth of plants and their environment. Model parameters are designed to be stable for a wide range of environmental conditions, and thus to allow characterizing genotypes. They offer new tools to analyze the genotype and environment interaction and they open new perspectives in the process of genetic improvement.

Research on plants enriches our intellectual life and adds to our knowledge about other life processes. The results of research on plant systems also can teach us how to approach problems in agriculture, health, and the environment.

Arabidopsis thaliana is considered to be an angiosperm (seed plant). Angiosperms are plants that produce flowers and bear their seeds in fruits. They are the largest and most diverse group within the kingdom Plantae, with about 300,000 species. Angiosperms represent approximately 80 percent of all known living green plants. *Arabidopsis* can be found along the shoulders of roads and in disturbed land.



Figure 1

Figure 1[1] shows *Arabidopsis* to be found along the shoulders of roads and in

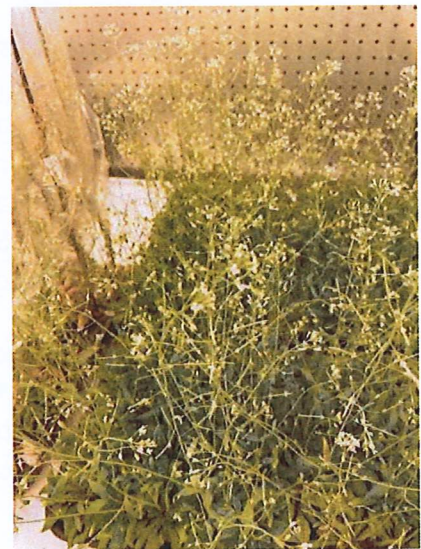


Figure 2

Figure 2 shows *Arabidopsis* at the laboratory which are genetically modified (transgenic)

Lefnaer, S. (2018, April 9). *Arabidopsis thaliana* sl19.jpg [Figure 1].

Focusing on the molecular genetics of simple angiosperms such as *A.thaliana* which is well known and used model organism in plant biology with a relatively short lifecycle and genetics has resulted in significant advances in understanding plant growth and development.

For instance, some research has been conducted focusing on the 120-megabase genome of *Arabidopsis*, and was found that is organized into five chromosomes and contains an estimated 20,000 genes. More than 30 megabases of the annotated genomic sequence have already been analyzed in GenBank by several laboratories in Europe, Japan, and the United States. (David W. Meinke et al 1992). All this research increases the validity and reliability of using *Arabidopsis* as a model organism in plant biology.

Furthermore, it was the first plant to have its genome sequenced and is a popular tool for understanding the molecular biology of many plant traits, including flower development and light sensing.

For my investigation, we will be measuring *Arabidopsis* hypocotyl. The *Arabidopsis* hypocotyl is a useful model for investigating the regulation of plant growth. Hypocotyl elongation in *Arabidopsis* is the result of regulated cell expansion that is under both environmental and hormonal controls.

✓ Clear knowledge
✓ use of terminology.

✓
A02
resource

✓
A03
logical order
- thorough understanding

antia is considered to be a liverwort plant meaning is a flowerless, spore-producing plant produced in small capsules. The spore capsule is the sporophyte and this grows from the stage.

phyte and sporophyte are the sexual and asexual phases that occur during the alteration of generations of plants. Both gametophytes and sporophytes are multicellular structures. The gametophyte produces male and female gametes directly from its plant body. In contrast, sporophyte produces haploid spores by meiosis. (An Australian Government Initiative, 2008).

Marchantia polymorpha efficiently propagates in favourable environments through clonal progeny called gemmae. Gemmae develops in cup-shaped receptacles known as gemma cups, which are formed on the gametophyte body.

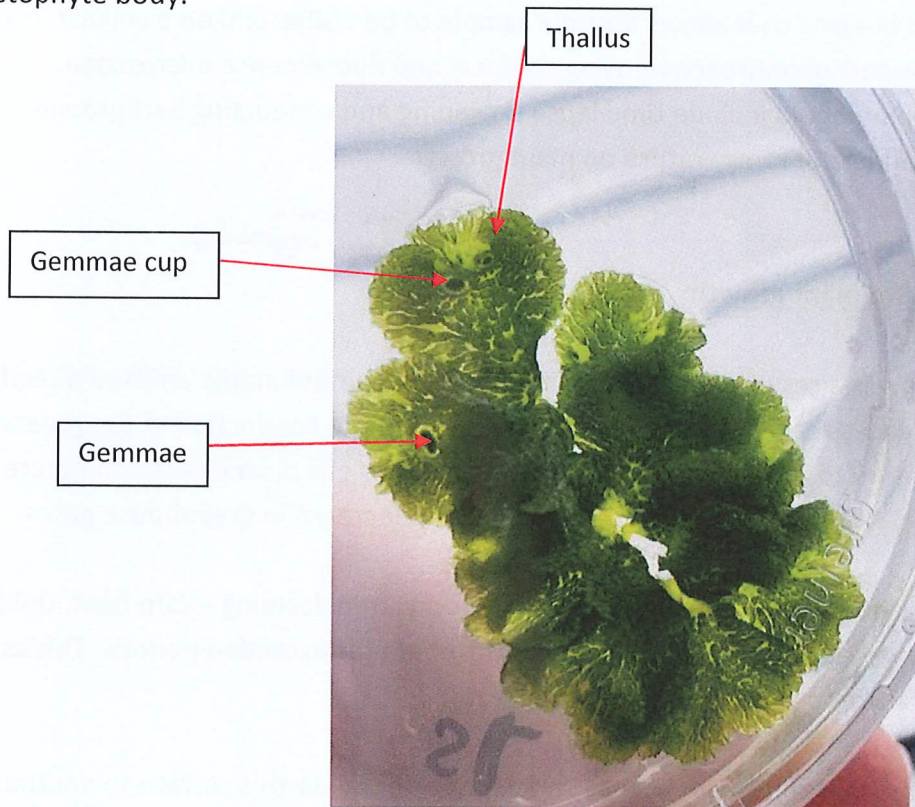


Figure 3

Figure 3 shows gemmae being developed in cup-shaped receptacles known as gemma cups, which are formed on the gametophyte body

saucer is a gemma cup and the lentil-shaped objects are gemmae. Gemmae allow the plant to reproduce asexually.

Approaches:

The approaches that can be used to investigate the effects of temperature on plant growth include the use of microscopy and genomic approach. The aim of functional genomics is to describe and understand the pattern of gene expression by looking at DNA sequences. Plant genomics is important as it can hugely benefit humans and help in areas such as food supply, sustainability of the environment, and health care. One means when identifying the useful gene it will be possible for the researcher by the additional use of gene transfer method to move genes with ease from one plant species to another. However, the genomic approach can provide great insight and data but it is time-consuming. Therefore, as my project had to be completed in a short time frame and due to young stages and model organisms, the use of microscopy

would be the best suitable option for me to pick. By using microscopy which includes the use of confocal and fluorescence microscopes, equipment for digital imaging, light-sheet, cryo-scanning electron microscopy (cryo-SEM), atomic force microscopy, and chemical imaging, allows to track living cells as they divide, grow and change shape to make a new flower. It is possible to observe the activation of important regulatory genes, for example those genes that protect plants from the pathogens. Additionally, Cambridge University by using microscopes when researching plants has identified petal surface structures that aid pollination and visualized the output of plant hormones within the seedlings. Therefore, this is a great example of how by using microscopes can provide us with well-detailed data to be analyzed.

For my research we have picked imaging as it allows a whole sample to be visible and on a cellular level observations are also possible as part of approach of using confocal and fluorescence microscope. Additionally, the time management would include time lapse imaging and conducting background information meanwhile, about effects of temperature on plant growth.

Planning +
resource
use.

considers some
approaches.

Temperature is known to regulate plant growth:

✓ more specific to question.

The main cause of global warming is a result of humans' increased use of air pollutants emitted directly into our environment, as these gases reach the atmosphere and result in the conduction of the greenhouse effect. When we draw our attention to the issue of global warming and its effect on plants and nature two notable factors arise to consider, which include climate change and an increase in greenhouse gases.

These air pollutants found in our environment absorb the sun's energy, transforming it into heat. Unlike naturally occurring atmospheric gases, they trap heat in the atmosphere for extended periods. This as result causes the global temperature to increase slightly over time.

Plants to keep our environment stable and clean, absorb some gases on the earth's surface to neutralize them before they reach the atmosphere through a process known as photosynthesis. Solar radiation is essential for plant growth. Plant leaves absorb sunlight and use it as the energy source for photosynthesis however increased solar radiation might result in heat stress which will show itself by wilting and eventually them drying out. At the moment, plants absorb 30% of carbon dioxide emissions annually (Ciais et al 2013) as result slowing the rate of global warming.

The consistently changing weather patterns as a consequence of the rising global temperature have serious negative impacts on the function of vegetation. For example, increased precipitation, drought periods, and natural disasters affect the development of vegetation.

research for these?

Plants are fully dependent on their environment for example their growth patterns, use of water, and flowering. For them to survive they will have to adapt and regulate their growth as a result of every coming summer becoming hotter. Because plants cannot migrate like some species, they grow taller to cool themselves off from the soil that absorbs the solar radiation and gets transformed into heat.

where get info from + what
research is there on this?

As they grow upward, their stalks become longer, their leaves shrink, and they grow farther away from other plants. The rise in plant height, and the increased distance between them, leaves the plants unsupported and unstable. Without other stalks to lean on, the plants are more likely to bend and break. Vegetation utilizes carbon dioxide to promote growth. As the human use of air pollutants increases, the growth of vegetation increases. Air composition alterations may stimulate the development of allergens and poisonous plant species.

As the global temperature increases, plants will flower earlier in the season. Earlier bloom times reduce the plant's ability to withstand the entire season. As precipitation decreases, flowers may bloom later in the season. This affects the species which rely on this bloom for food, shade, and more, and this as result will have an impact on the whole ecosystem and biodiversity. (Marsh, J. 2022, July 12). ✓

- How?

Temperature can act as one of the main factors that will affect the development and growth of the plant. Usually, you would think that most biological processes will speed up at higher temperatures, however they may have as equally negative as a positive one. For instance one benefit could be increased rate of fruit production and growth. However, the excessive respiration that occurs means that there is less energy for fruit development and the fruits will be smaller. This happens because usually when the rate of photosynthesis exceeds the rate of respiration, plants grow. If respiration exceeds photosynthesis, then growth declines, photosynthate (products of photosynthesis such as sugars) reserves are used, and plants become more susceptible to biotic and abiotic stresses.

It does have short and long term effects. For instance one example of immediate response of the plant on temperature is the balance of assimilations. The plant will always try to balance its consumption and production of assimilates. If there is an assimilate shortage, the plant has to cut down on consumption, at the cost of development or quality. Surpluses, however, mean inefficient utilization of available assimilates, which is also undesirable. Flower induction, which is the physiological process in the plant by which the shoot apical meristem becomes competent to develop flowers, can be determined by the climate over a much longer period. (Air temperature for plants | CANNA UK. (n.d.)

A03 more specific research
A02 needed + findings.

How to study plant development:

In order to determine the impact of temperature on plant development we track their growth over time in different temperatures. Timelapse imaging is a method of taking images at regular intervals. These images can then be used to compute growth rates. Different methods enable imaging at different scales. Low-resolution imaging usually it is for the whole organ to be visible and higher resolution is for cells based quantification.

At present, imaging techniques for plant phenotyping primarily include fluorescence imaging, thermal infrared imaging, visible imaging, imaging spectroscopy, and other techniques (MRI, PET and CT).

In order to visualise the plant cells fluorescent markers are used. Fluorescent markers are specific molecules, like protein, which are covalently bound fluorophores that selectively bind to a functional group of the target for detection, very often fluorescent proteins are used as a florescent marker.

The discovery of green fluorescent protein (FPs) in the early 1960s ultimately started a new era in cell biology, allowing monitoring cellular processes in living systems using optical microscopy and related methodology. Additionally it's coupled to recent technical advances in wide field fluorescence and confocal microscopy. *Research studies - what approaches do the study's use?*

In 1960s it was first time when a calcium-dependent bioluminescent protein was isolated from the jellyfish. During the isolation procedure, a second protein was observed that lacked the blue-emitting bioluminescent properties of aequorin, but was able to produce green fluorescence when illuminated with ultraviolet light. Due to this property, the protein, it was eventually named as green fluorescent protein (GFP).

Although the gene for green fluorescent protein was first cloned in 1992, the significant potential as a molecular probe was not realized until several years later when fusion products were used to track gene expression in bacteria. Since these early studies, green fluorescent protein has been engineered to produce a vast number of variously colored mutants, fusion proteins, and biosensors that are broadly referred to as fluorescent proteins.

More recently, fluorescent proteins from other species have been identified and isolated, resulting in further expansion of the color palette. With the rapid evolution of fluorescent protein technology, the utility of this genetically encoded fluorophore for a wide spectrum of applications beyond the simple tracking of tagged biomolecules in living cells is now very valuable. (Piston, D. W et al.)

The adaptation of fluorescent proteins is hugely beneficial in the use of plants, fluorescent protein tags marking expression profiles or genuine proteins of interest have been used to recognize plant tissues and cell types, monitor dynamic cell fate selection processes, and obtain cell type-specific transcriptomes. Fluorescent tagging enabled the visualization in living tissues and the precise recordings of dynamic expression pattern changes.

In developmental studies, the use of fluorescent proteins has become critical, where morphological markers of tissues, cell types, or differentiation stages are either not known or not easily recognizable. *A02 A03*
(Ckurshumova, W., Caragea, A. E., Goldstein, R. S., & Berleth, T. 2011).

Imaging at different wavelengths is used for different aspects of plant phenotyping. Visible imaging is primarily used to measure aspects of plant architecture such as image-based projected biomass, leaf area, colour, growth dynamics, seed morphology, root architecture and distribution. *Briefly. not specific enough for top band.*

Fluorescence imaging is a type of non-invasive imaging technique that can help visualize biological processes taking place in a living organism. Images can be produced from a variety of methods including: microscopy, imaging probes, and spectroscopy. Confocal microscopy is widely used for fluorescence imaging in the life sciences.

Confocal microscopy uses light from a laser through the objective of a standard light microscope to excite a specimen within a narrow plane of focus. Some advantages of using confocal microscopy is that you are able to image living samples in situ for example plants, it's possible to make 3-D images and can image samples in water or other media meaning no vacuum is required. However, it requires an epi-fluorescent sample or a fluorescent labelled sample and the magnification is limited by the optical excitation wavelength.

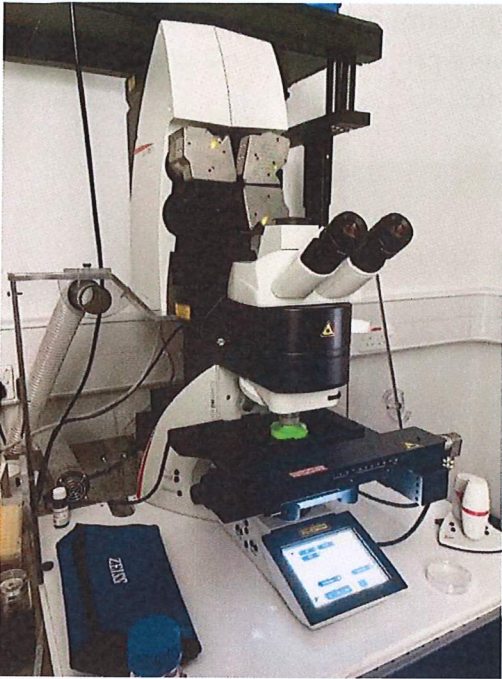


Figure 4

Figure 4 demonstrates **Leica SP8 Confocal** microscope at the laboratory used for imaging *Marchantia*



Figure 5

Figure 5 demonstrates **Olympus fluorescence zoom** microscope at the laboratory used for imaging

Imaging spectroscopy can provide insight into the drivers of growth dynamics by means such as measuring growth patterns during experiments and also for gathering plant spectroscopy data to quantify vegetation indices, water contents and the composition parameters of seeds.

Methodology: Plant growth conditions

To investigate the effect of temperature on *Marchantia* growth and development I have first prepared the media. Media has three main functions. It supplies roots with nutrients, air, and water. It allows for maximum root growth and physically supports the plant. It is used instead of soil. Usually, media are stored in a solid form therefore we placed it into the boiling water bath for thirty minutes in the order for it to melt and then pour it into the Petri dishes.

Has this come from research?



Figure 6

Figure 6 shows different types of media for specific use and research aims



Figure 7

Figure 7 shows a water bath with boiling water where media is placed



Figure 8

Figure 8 demonstrates the four samples I used containing gemma

Moving on, when the Petri dishes were ready with media , Gemmae was taken from a 3 to 4 weeks old plant Marchantia , using cocktail sticks and grown on one-half-strength Gamborg B5 Basal media for one day. Four petri dish containing B5 Basal media with gemmae inside were prepared, where 2 would have been placed at 21°C and the other 2 petri dish at 28°C in growth cabinet.



Figure 9

Figure 9 demonstrates a growth cabinet at 28°C



Figure 10

Figure 10 demonstrates the inside of growth cabinet at 28°C

Afterwards, Arabidopsis seeds with plasma membrane YFP were surface sterilized with ethanol in a lateral flow hood and sown on ½ MS media. Seeds were put in the fridge at 4°C for 2 days to vernalize. Vernalization its essential as it acts as artificial exposure of seeds to low temperature in order to stimulate flowering or enhance seed production. Then they were moved to the growth cabinet and placed to grow vertically into 2 different conditions, 2 samples being placed at 21°C and the other 2 at 28°C. AP3



Figure 11

Figure 11 shows lateral flow hood that protects the working environment from dust and other airborne contaminants by maintaining a constant, unidirectional flow.



Figure 12

Figure 12 shows seeds of Arabidopsis being sterilised with ethanol

Imaging:

The next day the samples were taken to the Olympus fluorescence zoom microscope for imaging and collection of data. Special software was used to take snapshots of gemmae under the microscope.

Magnification was used to enable the whole sample to be visible.

We excite gemmae samples with green light, and then the marker we used was RFP which is red fluorescent protein which is why it looks red through the eyepiece at the Figure14.

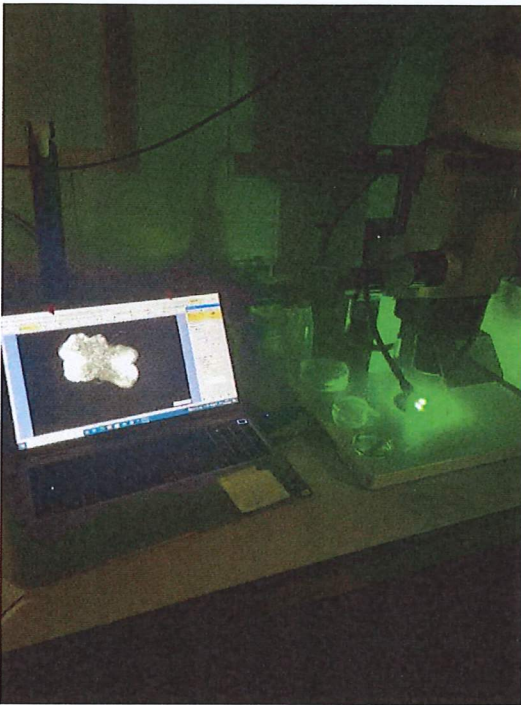


Figure 13

Figure 13 shows the Olympus fluorescence zoom microscope and gemma being imaged on the software

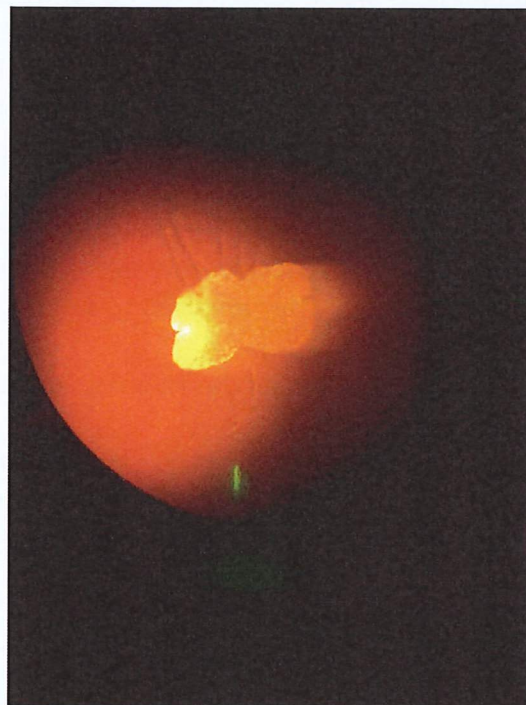


Figure 14

Figure 14 shows gemma under the microscope

Around 15 snapshots were taken for each condition at day two and three .Equally, same microscope would be used to take snapshots for Arabidopsis specifically hypocotyl for day three, four and five, around 15 snapshots for each condition and for each day being imaged.

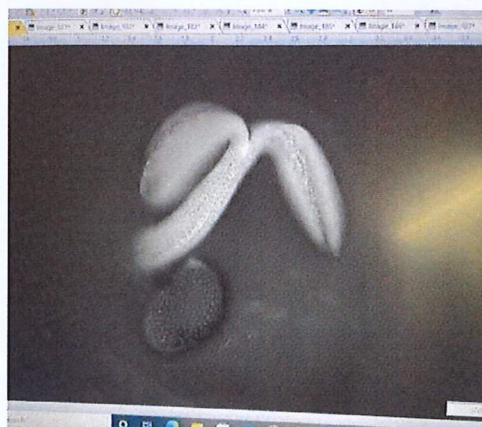


Figure 15

Figure 15 demonstrates hypocotyl under the Olympus fluorescence zoom microscope

Safety and ethical issues:

One of the most important safety guidance when working in a laboratory with genetically modified (GM) plants it is to prevent them not to leave the boundaries of the laboratory into the open environment. GM is a technology that involves inserting DNA into the genome of an organism. To produce a GM plant, new DNA is transferred into plant cells. Usually, the cells are then grown in tissue culture where they develop into plants. The seeds produced by these plants will inherit the new DNA.

Some of the major risks include the transfer of antibiotic resistance, toxicity and allergenicity. For example, herbicide resistance in crops can reduce in-field biodiversity that may reduce the ecological services provided by agricultural services. Therefore, before transferring the GM plants into the environment all the risk should be carefully quantitatively assessed. Some approaches that are used as part of risk assessments include tiered approach. However, if GM plants will be taken to the environment without any awareness it might have a negative impact on ecosystem. Therefore, to prevent that we were using lab coats in growth chamber. Also, autoclave waste was used which work with a combination of steam, pressure and time. Autoclaves operate at high temperature and pressure in order to kill microorganisms and spores. They are used to decontaminate certain biological waste and sterilize media, instruments and lab ware.

Finally, it is also important to label the samples so they do not get messed up.

Some ethical issues using transgenic plants includes potential harm to human health, negative impact on traditional farming practice and the use of unnaturalness of the technology.

Cellular measurements:

After some sample imaging of gemma on fluorescence zoom microscope we decided to have a look at the sample on a cellular level to see whether there is a particular difference in a specific zone of gemma that it's more sensitive to temperature by using Leica SP8 Confocal microscope. We had used gemma from ✓
Marchantia that was 16hours old. The TUB-GFP lines in Marchantia excited with 488nm laser and emission detected in 490-540nm range. Z-stack was collected with 1um step size. One image was taken for 21 degree and 1 for 28 degree.

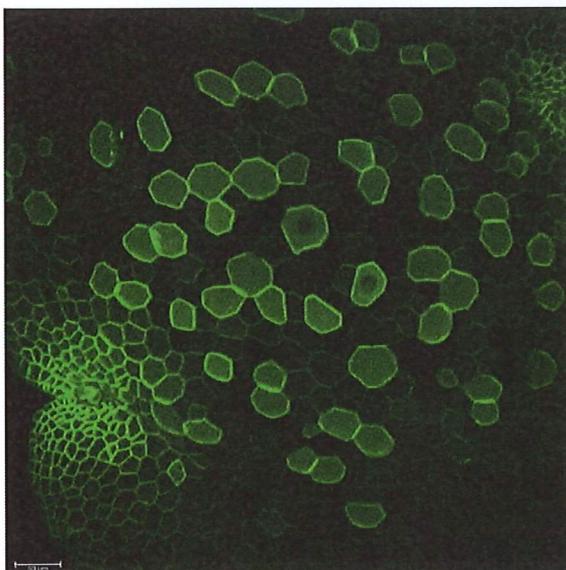


Figure 16

Figure 16 shows Marchantia under a fluorescence zoom microscope at 21C

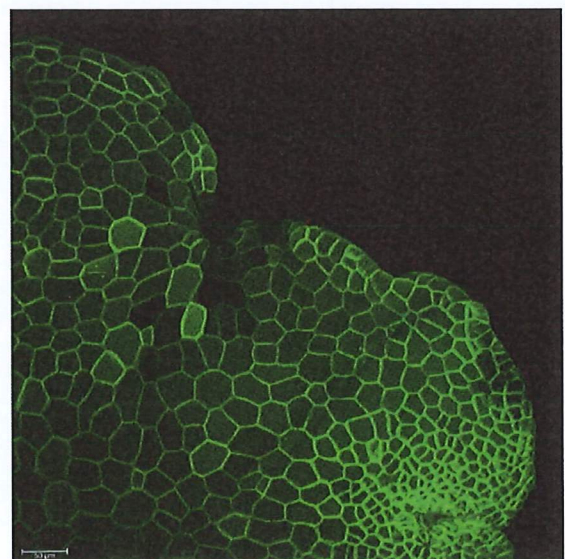


Figure 17

Figure 17 shows Marchantia under a fluorescence zoom microscope at 28C

Image analysis:

All the images were transferred to the USB and uploaded on special software called Fiji. Fiji is a distribution of popular Open Source software focused on biological image analysis. This software enabled me to record and save data. I calculated the area of gemma and cells there and measured the total length of the hypocotyl. After the collection of data, I organized it into a table at a program called excel for each species and day (tables can be seen in the Appendix section). ✓ A02

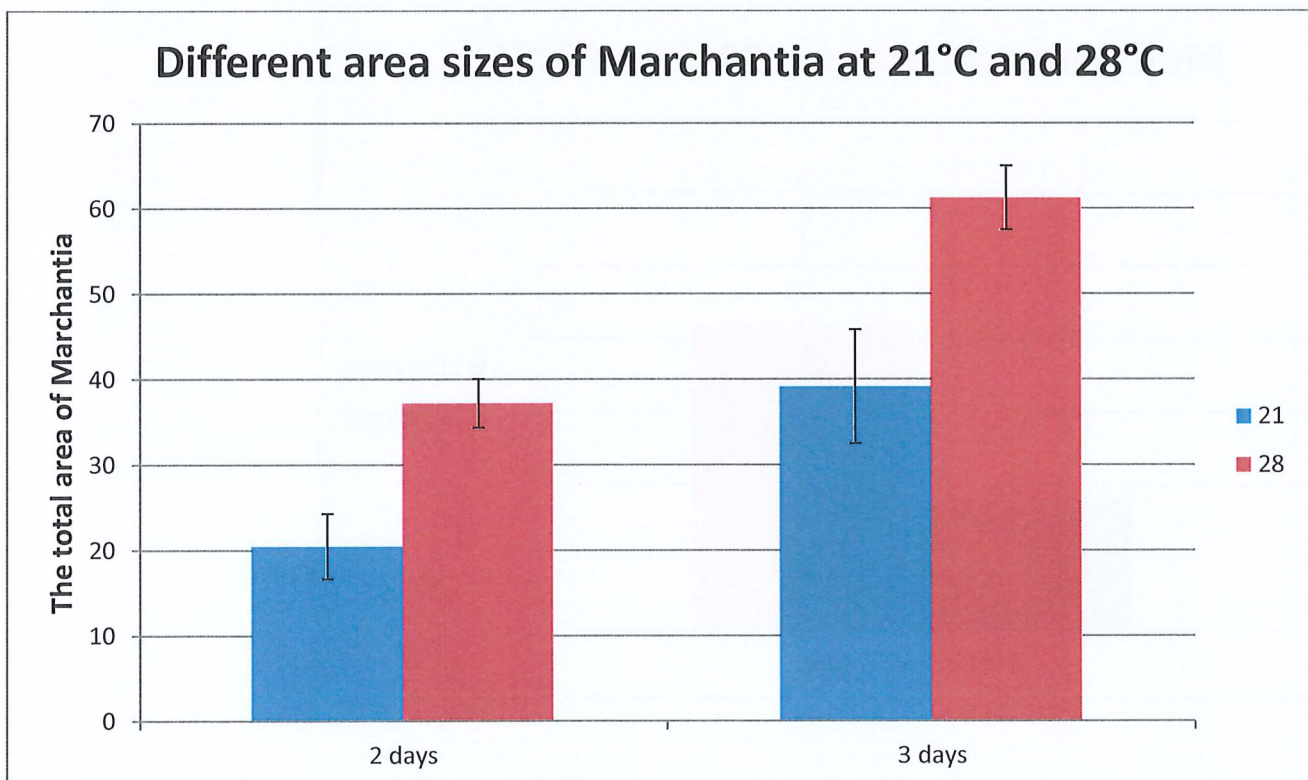
Then I have taken an average and conducted a t-test with standard deviation included, afterwards, the data was transferred into the error bars where I could analyze the distributions of values from the mean and make conclusions. Additionally, percentage change was also done for each day for Marchantia and Arapodopsis at 21°C and 28°C degrees which allowed me to compare the rate of growth within different conditions and days. A02

Results and discussion:

A03.

To determine the impact of temperature on Marchantias growth we have measured the gemma area in 2 conditions.

From results collected for Marchantia, they demonstrate that there is a difference in size when the plant is grown at 21°C and 28°C.



For instance, the results above show that the greatest average of the total area is found at 28°C compared to when grown at 21°C, for example, the average is 60um being at 21°C, and being at 28°C is 98um. It also demonstrates that on a third day Marchantia is significantly bigger in area, for example, the percentage

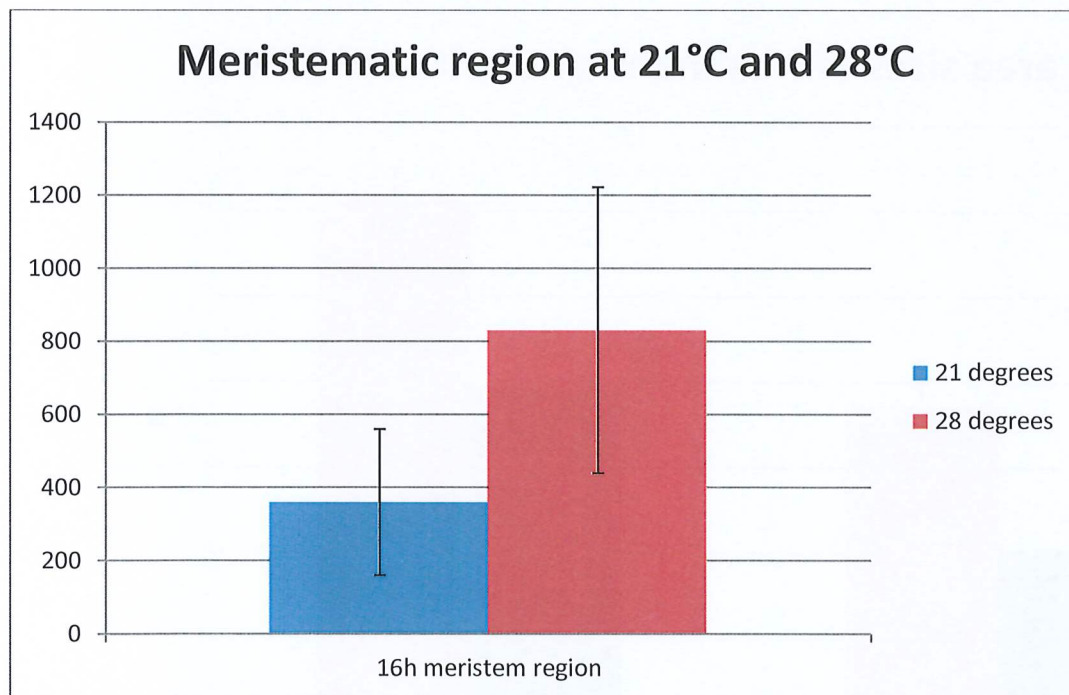
change between the second day and the third day at 21°C is 91.2% which means there is also a big impact on how long the plant is found in a certain condition, in this case, the temperature is at 21°C.

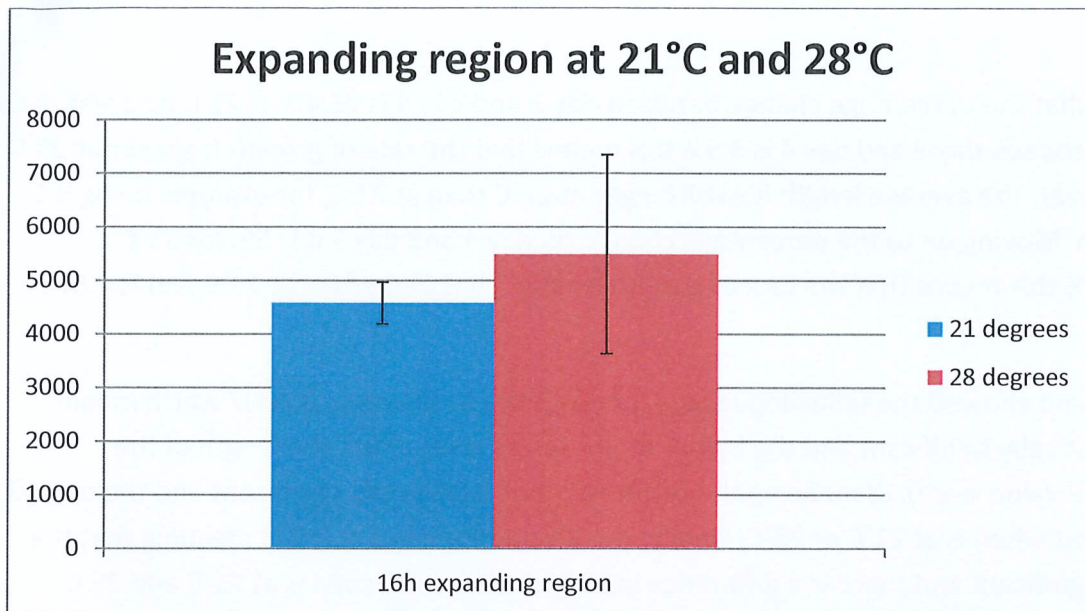
In contrast, with Marchantia being at 28°C the percentage change it's much smaller between the second day and third day for instance 64.6% this means that the rate of growth is slower at 28°C than at 21°C, perhaps because the plant has adjusted to this specific temperature. This highlights that if plants are placed at higher temperatures doesn't necessarily mean that they will divide faster to get bigger in size. *Eval/ Disc. conclusion?*

The two SEM error bars above do not overlap meaning the P value could be less than 0.05 meaning that the difference is statistically significant and therefore the temperature does affect the growth and development of Marchantia. *✓ AB2*

A T-test was performed which gave the value of 0.0006 for 2 days and 0.0002 for 3 days. The results are statistically significant, which indicates strong evidence against the null hypothesis, as there is less than a 5% probability the null is correct and the results are random. Therefore, we reject the null hypothesis which would be that 'high temperature does not affect plant growth', and accept the alternative hypothesis which would be that 'high temperature does affect plant growth'. *conclusion? Hypothesis*

Afterward, we decided to check gemma cells on cellular level under the microscope to check where the main difference can be. Cells were compared in two regions meristematic and expanding.

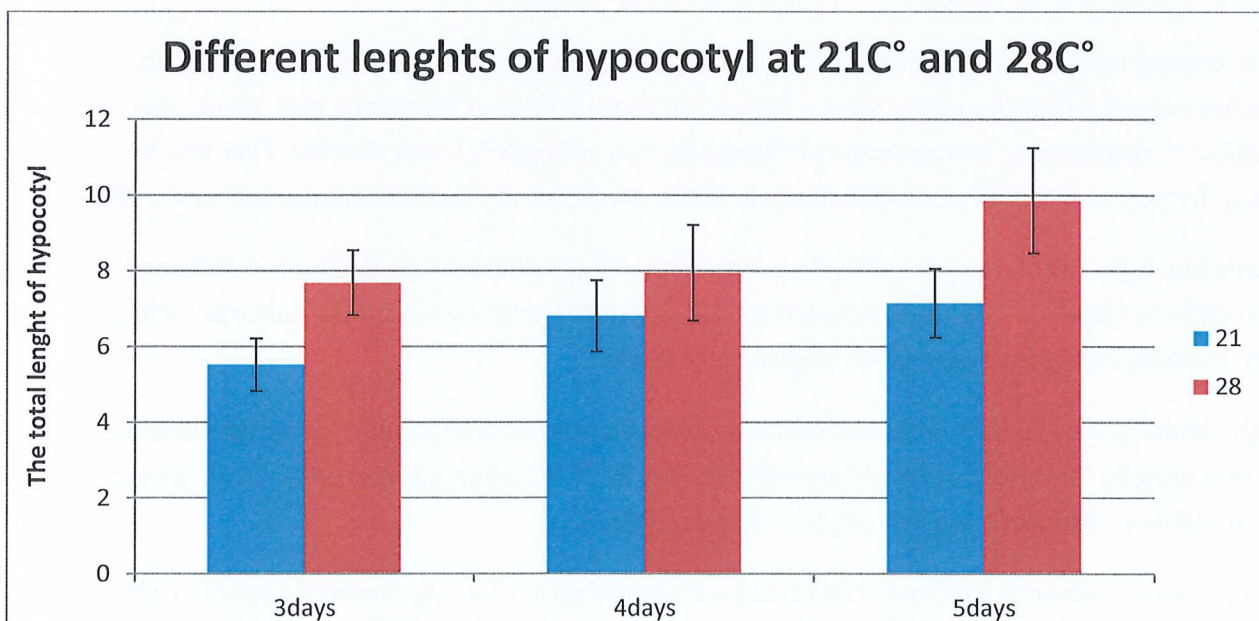




The data above from error bars demonstrate that there is a significant difference in the meristematic region at different temperatures, for instance, the percentage change is 133.6% whereas in expanding region the percentage change is only 10.7%. We may infer from this result that the meristematic region is more sensitive to an increase in temperature and therefore undergoes more cell divisions. ✓ A02

Additionally, the t-test was carried out and showed that the P value is less than 0.05 for the meristematic region which is 0.01, which means that the results are statistically significant whereas for expanding region is 0.11 which means that the results are not statistically significant, that means there is not a huge impact of temperature on the expanding region meaning its less sensitive to the environmental changes.

Moving forward to determine the impact of temperature on Rapadopsis growth I have measured the length of the hypocotyl in two conditions.



The results above show that the percentage change between day 3 and day 4 is 23.4% at 21°C whereas the percentage difference between day 3 and day 4 is 3.5% this means that the rate of growth is slower at 28°C compared to 21°C, however, the average length it's still bigger at 28°C than at 21°C, for example being 5.5 mm compared to 7.7mm. Moving on to the percentage change on day 4 and day 5 it is 5% for 21°C whereas for 28°C it is 24% this means that the rate of growth by day 5 has decreased at 21°C and for 28°C increased.

A T-test was performed and showed the following results for day 3 the P value was 0.0007 which means that the results are statistically significant and the higher temperature does affect the length of the hypocotyl. On day 4 the P value was 0.12 meaning the results are not statistically significant and the overall length is not very different when is at 21°C or 28°C. Finally, the P value for day 5 is 0.003 meaning that the results are statistically significant and there is a difference in length when hypocotyl is at 21°C and 28°C meaning that higher temperature does affect the cell expansion of Arabidopsis.

AR2

Combines some discussion.

Conclusion:

From the results above we can conclude that Marchantia and Arabidopsis grow better in higher temperatures, in this case, being at 28°C compared to when it's found at 21°C at the duration of 3 days for Marchantia and 5 days for Arabidopsis.

Finding.

However, further experiments will be required to confirm this. For example, what is the long-term effect of being in higher temperatures, what genes are being affected, and perhaps can we apply the finding to other species or maybe it can be true to all plants, therefore further research will be required.

Considers future research.

Some studies studying the effects of temperature on plant growth have proposed that plants display architectural plasticity in response to their surrounding environment via changes in organ shape or size by regulating basal cellular processes like cell division and expansion. This means that plants respond to their environment instantly through adaptation by altering biological functions.

Defence?

For instance, several reports have highlighted the importance of cell proliferation (cell division) in mediating plant growth plasticity under various environmental stimuli. This means that plants can change their phenotype in response to environmental change by controlling their cell division. (Tardieu and Granier, 2000; Rymen et al., 2007; Casadevall et al., 2013; Okello et al., 2016; Romanowski et al., 2021).

Findings?

This is achieved by tight regulation of cell cycle progression. High temperature does elicit different growth responses in different organs. The most well-known response to various environmental cues including temperature is called cell elongation which promotes growth.

The research conducted by K. Saini et al has found a positive correlation between how high temperature suppresses leaf area by inhibiting cell division in the leaves at 28 °C when compared to 21 °C grown Arabidopsis at 20 days. (K. Saini, A. Dwivedi, & A. Ranjan, 2022).

Some discussion links, however doesn't provide to any study specific fully

Furthermore, one behavioural response that plants can demonstrate by responding to light is called shade avoidance syndrome, which is responsible for the changes in plant body form and function. Also, known as

growth plasticity where plants exhibit various architectural adaptations including the elongation response to compete with neighboring vegetation for light (Pierik and De Wit, 2014). One of the possible impacts of plants competing against different species for light can be reducing biodiversity.

From the research above my findings are contrasting and the conclusions are different for instance because the research was carried out for a much longer time which was 20 days compared to mine which was 5 days for Arabidopsis. The results suggested that prolonged high temperature reduced leaf area by negatively impacting cell number which could likely result due to temperature-mediated inhibition of the cell division process.

This suggests that further research and experiments should be carried out in order to gain valid and reliable data to increase the generalisability of it.

I have learned once again how important is do conduct research in areas such as plants as it enriched our understanding of many life processes and how we are all interdependent on each other. In order to come up with effective good solutions the research should start from very start and detail analysis. For example when looking at genome and comparing it to how it has evolved and its function, all require time and attention. Therefore, it is also very important to follow standardised operationalised procedures. Additionally, I have noticed that it alright not to know everything and secondary research it is a great foundation to start off. Also, effective communication with lab members has also led to motivation of learning something new and being responsible as you should stay on track and be organised.

Brief Eval of invest.

For future, I would spent more time analysing secondary resources, their reliability, validity and reading more of them so I can form a stronger idea of the topic I am researching. I would also repeated the experiment several times and use more samples.

Area that is lacking
A03

Appendix

days	21degrees	28degrees	SD21	SD28	T-test
2 days	20.4762	37.22	3.826096928	2.867098272	5.09142E-05
3 days	39.1478	61.2602	6.661854336	3.740963338	0.000193842

Figure1

Figure 1 shows all the data points together for Marchantia for days 2 and day 3 at 21C and 28C.

days	21degrees	28degrees	SD21	SD28	T-test
3days	5.518	7.683166667	0.696891	0.855221	0.000715624
4days	6.808666667	7.949166667	0.940382	1.265923	0.106890299
5days	7.151166667	9.853	0.91219	1.390481	0.002602421

Figure 2

Figure 2 demonstrates all data points of Arabidopsis for days three, four, and five at 21C and 28C

	21 degrees	28 degrees	SD21	SD28	T-test
16h meristematic region	359.875	830.875	277.5605146	391.2753643	0.01483711
16h expanding region	4581.875	5491.5	391.2753643	1856.912346	0.11024846

Figure 3

Figure 3 shows all the data points of Marchantia under cellular imaging for 16h at 21C and 28C

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Additionally, I was trying by the time working and being at the laboratory, always ask people who worked there advice and questions about my topic research and broader to do with plant biology which gave me a great hint on what journals and articles I should read and where I should conduct some secondary research.

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