Inquiry-based time-lapse video projects in introductory plant physiology

Final report to the NV Faculty

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Funding for the project was granted in late May 2018, during my 2017-18 sabbatical leave. Consequently, the project was implemented in the introductory course BI1007, Plant Structure and Function, in the autumn semesters of 2018 and 2019, as specified in an updated timetable. BI1007 is a required course in the BBI, MBIOT5, and LUR biology/chemistry degree programs, with usually about 120 students in the course.

Autumn 2018 semester

In the first semester, students were given the option of doing a time lapse project in lieu of one of the regular lab exercises in the course. The project was introduced and explained in lecture and in announcements on Blackboard. Interested students were invited to a brainstorming session and then invited to submit proposals specifying a research question and methods, including experimental treatments and quantitative measurements made from the video or directly on the experimental subjects (Appendix 1). Five pairs of students applied to do projects, all of which were approved and completed.

Title	**Measurements**	**Duration**
How is the anthocyanin concentration in leaves of *Pelargonium* sp. affected by light stress?	Relative anthocyanin concentration in leaf extracts	21 days
Investigating the effects of gaseous ethylene on pea (*Pisum sativum)* hypocotyl and young shoot	Hypocotyl length and circumference	9 days
Leaf expansion in *Pilea peperomioides*	Relative change in leaf area	21 days
Effect of ethylene on water uptake in carnation	Color change in white flowers	2 days
The effects of auxin on aerial root growth in *Ficus* plants	Root length	30 days

Further work on the projects involved the students meeting with myself or a dedicated lab assistant, Kristine Marie Svanø, for further planning, advice, and help with set-up and execution. This involved some extra purchases for plant material and mounting cameras and lights and some trial and error to get all the elements well-positioned. Kristine Marie and I worked together to evaluate the projects, awarding four B and one A grades.

Video quality and technical issues

The final two projects in Table 1 were unsuccessful in producing useful videos due to limited plant responses to treatment, but in both cases the students produced a satisfactory report describing the procedures and problems with the results. The other three succeeded in producing videos and measurements that addressed the research question, all detailed in their reports. There were problems with banding on videos recorded under greenhouse or fluorescent light. The camera vendor proposed some solutions, but they only partially ameliorated the problem. We later found that we can get satisfactory results using the LED grow lights that we purchased as part of the project, as long as there is no background fluorescent light. Although the cameras have limited HDR capability, we also had problems getting satisfactory exposure. Finally, the relatively long duration of the processes that three of the groups chose to study resulted in variable light conditions, including day/night cycles, that further affected video quality.

Second round in 2019

All of these lessons were applied in the second iteration in 2019, where we recommended in particular that students work with shorter term responses such as tropisms or sleep movements, as well as trial videos to get good lighting and exposure.

In 2019, only one group of three students decided to take the time lapse option. Their project on effects of light color on leaf movements in *Oxalis triangularis* resulted in a high-quality video that clearly demonstrated differences in response to light color, supported by measurements of leaf angle taken from the video, and confirming that leaf movements are primarily a blue light response. The video was further used in teaching in BI1007 in autumn 2020 to demonstrate the effects of light color on leaf movements and as an example of a student-produced video. Unfortunately, no students have engaged in time lapse projects in 2020, perhaps in part due to problems imposed by the Corona pandemic.

Evaluation and future development

After the projects were completed in 2018, I met with some of the students in an informal reference group to discuss the pros and cons and learning value of the projects. All the students indicated that the extra time involved in completing the projects was time well spent, with high learning value in both planning and completing a small research project and dealing with hands-on technical issues. Six of the eight students who completed projects in 2018 and one of the three in 2019 have enrolled in 2000 level courses with me, including three in BI2021 Plant ecophysiology in autumn 2020.

As evidenced by the limited participation, I overestimated the number and engagement of students to take the time lapse option. Those that did were very engaged and did good to excellent work. The future challenge is in doing a better job of selling the time lapse option to students who are not necessarily engaged by plant physiology and uncertain about the learning value of this kind of project. To the extent that more students do engage in independent projects, there may also be issues around the time needed to supervise and evaluate them.

I plan to use the cameras in a BI1007 H21 lab exercise on the effects of plant hormones on gravitropism and of light color on phototropism in maize seedlings. These are relatively rapid processes, so recording can be completed in a few hours. The videos will allow students to see the plant responses “in action”, and as part of the report they will measure the degree of tropic response in the videos and analyze the resulting data. I will also keep the independent project option open.

Budget

As planned, the project funds were used to purchase 16 time lapse cameras, lighting and mounting equipment, some plant material, and for hourly pay for a lab assistant in 2018 (Appendix 2). As of October, 2020, there is NOK 5773 remaining, which will be transferred to the maintenance budget for the BBI greenhouse, D1-124. The greenhouse is used almost exclusively for teaching, including some of the time lapse projects.

Appendix 1. Description of the time lapse project option

BI1007 H20 Plantenes struktur og funksjon

The Time Lapse Option

As you will see during class, time lapse videos can be used to speed up plant movements and gain insight into how plants grow and respond to their environment. We want to pass this powerful visualization tool on to our students. We have purchased some dedicated time lapse cameras that you can use to produce you own short videos of plants in action. You can substitute a report on a time lapse video project for one of the last two reports in the lab course. In order to exercise this option, you must first submit a project plan for approval. Because we have a limited number of cameras, not all projects will be given a green light, but we hope to see some diverse and interesting proposals.

In general, we expect these projects to be planned and executed by lab partners, but we may give the go ahead to somewhat larger groups for more ambitious projects. It is up to all partners to agree on how to divide the work; everyone in a group will receive the same grade.

Time lapse power

We will be using Brinno TLC 200 pro time lapse cameras. They come with a standard wide-angle lens that can focus to within a few centimeters for working with small subjects such as germinating seeds. We also have a few zoom lenses with IR filters for added flexibility. We do not have microscope adapters, but it may be possible to shoot through a microscope as is often done with mobile phone cameras. The cameras are overall rather simple but can be adjusted for different time lapse rates and light conditions. In general, you should plan for your videos to run for one to no more than five minutes, which you can do by estimating how long the process you want to study will take and adjusting the time lapse rate accordingly. In addition to the user's manual, we will provide a technical guide that will help you get set up.

Plant material and facilities

You can use any plant species, organ, or tissue type that you like, limited only by availability. However, based on our experience from last semester, we encourage you to work with relatively rapid responses such as seed germination or tropisms in seedlings. Your project should involve "plants in action", growing or responding to the environment at rates that are too slow to perceive in human time. For some ideas you can take a look at the (old and low-resolution) videos on the [Plants in Motion](http://plantsinmotion.bio.indiana.edu/) web site (http://plantsinmotion.bio.indiana.edu/) – but we would be very happy to see some original ideas as well!

We have a variety of seeds in storage and plants growing in the greenhouse that are available for you to work with. We also have a small budget for purchasing new plant material at a garden shop or nursery. You are welcome to provide your own plant material if you choose.

We have or can make available:

- 16 Brinno TLC200 pro time lapse cameras
- 2 Waterproof housings
- 2 each 24-70 and 18-55 zoom lenses with IR filters

- seeds: maize, barley, oats, sunflower, tomato, bean, radish, cucumber, miscellaneous others
- other seed can be ordered
- plants in the greenhouse: Coleus, oyster plant, scented geranium, insectivorous plants, miscellaneous others (take a look around!)
- various soil mixes and soil amendments
- pots of various sizes in the greenhouse
- stakes, tape, sticky tack, twisties and string (for anchoring plant material)
- petri dishes and filter paper (i.e. for seed germination)
- agar
- nutrient solutions
- common plant hormones
- common biological buffers
- mannitol and PEG (used for adjusting water potential)
- a variety of tripods, clamps, and other equipment for working with the cameras

If there's anything else you need, ask and we'll see what we can do!

In addition to the greenhouse, we have access to growth chambers with controlled light and temperature that may be available if they aren't being used for other projects. We have ordered red, far-red, blue, and green light sources and can set up directional lights for phototropism experiments in the darkroom in D1-114.

Brainstorming session TBA

We will hold a brainstorming session to test and share ideas for the projects. To be fully prepared for this session, you should read this handout thoroughly and more than once, check out some of the Plants in Motion videos or search for and run time lapse videos of plants in action on You Tube or other sources, and look through the plant section of our textbook or other books for ideas. The possibilities are endless!

We will have an online sign-up for the session and announce the room and time later.

Proposals due 16. September

Your proposal should be no more than two pages long and should focus more on the practical details than theoretical background. Here are some tips:

- Start with a few introductory sentences leading to a research question.
- Your study design should involve plants growing under or responding to two or more different treatments (for example light, water, temperature, nutrients, or hormones), but you should try to keep it simple
- You should replicate the treatments if feasible, but we will relax the usual scientific requirement for replication if necessary, in which case you can present your results as "preliminary". Treatments and replicates can be filmed in one or separate videos, depending on the demands and constraints of the experiment
- Your plan should also include some other measurement of the plant's growth or response, either by stopping the video at intervals and measuring some dimension (include a ruler or other scale in your video) or perhaps by measuring some

experimental replicates that are not in the video. You can then calculate a rate of change or perhaps other parameters to include in your report.

- Provide an overall schedule for the project, with internal deadlines for setting up, recording the video, and reporting
- Specify how many cameras you will need, how long you will need them for, and when you would like to start using them.
- Identify or list any other equipment that you will need
- Provide details about how and where you plan to set up your plant material and the camera(s)
- Specify light, day length, temperature or other conditions where relevant
- Estimate how long the process you want to record will take and the time lapse rate you will need to make a one to five-minute video at 30 frames per second*

*Do the math:

Video length min = (event length hr * 3600 sec/hr) / (lapse rate sec/frame * playback rate 30 frames/sec * 60 sec/min)

Appendix 2: Budget

Leverandør/Kunde	Bilagskat	Linjebeskr	Val beløp	Val	Beløp i NOK
	Korreksjon/ompostering	Inquiry-based time-lapse video: Tilskudd NV 2018	- 100,000.00	NOK	- 100,000.00
	LØNN	SVANØ,KRISTINE MARIE	22,660.00	NOK	22,660.00
	LØNN	SVANØ,KRISTINE MARIE	3,195.06	NOK	3,195.06
SCANDINAVIAN PHOTO AS	Inngående fakturaer	Tripods and table mounts	8,226.00	NOK	8,226.00
INTERFOTO AS	Inngående fakturaer	Tripods and table mounts	5,356.00	NOK	5,356.00
PLANTASJEN NORGE AS	Inngående fakturaer	Plant material	873.40	NOK	873.40
PLANTASJEN NORGE AS	Inngående fakturaer	Plant material	162.80	NOK	162.80
CLAS OHLSON AS	Inngående fakturaer	Lights, batteries, SD cards	261.00	NOK	261.00
CLAS OHLSON AS	Inngående fakturaer	Lights, batteries, SD cards	876.00	NOK	876.00
PLANTASJEN NORGE AS	Inngående fakturaer	Plant material	139.80	NOK	139.80
SCANDINAVIAN PHOTO AS	Inngående fakturaer	Table mounts	4,212.00	NOK	4,212.00
PLANTASJEN NORGE AS	Inngående fakturaer	Plant material	59.90	NOK	59.90
PRO TECH AS	Inngående fakturaer	Time lapse cameras	40,250.00	NOK	40,250.00
CLAS OHLSON AS	Inngående fakturaer	Lights, batteries, SD cards	837.00	NOK	837.00
	LØNN	STRIMBECK,RICHARD	7,018.00	NOK	7,018.00
	Korreksjon/ompostering	NV Finmek.verksted 2018-485, Kristine Marie Svanø	100.00	NOK	100.00
					-5,773.04