Logbook by Ariel and Ella

Oct 1, 2023 – Ariel and Ella started thinking about science fair. Both Ella and Ariel decided to do a project together. We both had the same idea to work on agrivoltaics and were excited to see if we could make it work!

Oct 4, 2023 – Developed questions that we wanted to test. Some ideas were to look at the agricultural crops and observe which crop grew the best. Other ideas revolved around the placement of the solar panels and their transparency..

Oct 11, 2023 – Ella set up and cleaned her basement to make room for the panels and plants.. The next step is to order models. Models will take up approximately 1 x 1 foot per model. Each model will contain the solar panel, the plant, and the artificial "sun" suspended above. The plants we will start with will be mustard seeds.

Ariel started researching on the specifics of mustard plants. Mustard crops can grow up to 45 inches but can be as long as 30 inches. For mustard to fully mature, it takes anywhere from 80 to 95 days. The plants grow more quickly with a higher moisture and temperature environment.

Oct 14, 2023 – Created a method for Stem Science Fair Club. We included our question for this experiment, the hypothesis for each question, points for initial background research, all the variables, and our planned out time frame. The first draft is shown below.

Science Fair Outline

By: Ariel and Ella

Question:

How can we optimize agrivoltaics?

1. Which height of solar panel is best using agrivoltaics?
2. What transparency solar panel is best using agrivoltaics?
3. What is the best way to harvest plants while doing the process of agrivoltaics?

Hypothesis

Here is the hypothesis for this experiment.

Main Prediction

We hypothesize that the plants that grow in shade will show the most promising results. We think that with the right height and harvesting technique we can grow plants faster because of the reduced amount of direct sunlight. When the plants do not get as much sunlight, the solar panels will be tall enough to absorb the UV rays and turn them into viable energy.

Prediction for Each Question

1. We predict that the best height for the solar panel will be a minimum of the height of the machinery used to harvest the crop. This is because we want to reduce the risk of damaging the solar panels and the harvesting machinery, we need them to be far enough apart. But, we do not want the solar panel to be too high, so that it blocks the plants from any sunlight.

2. We predict that the solar panels will need to be semi transparent, so that the plants that are grown directly under the solar panels can get enough sunlight. The transparency of the solar panels may change throughout the separate tests so that the different crops can get the amount of sunlight that they need.

3. We predict that while agrivoltaics is happening with the right spacing and height harvesting can go as it normally would. The harvester may have to go in a different direction but harvesting will stay the same.

Overall Prediction

Overall we predict that more direct sunlight that the solar panels get, will result in more energy and a faster growth rate of certain plants that could be used in agrivolatic fields. We believe that the height of the solar panel will affect how well the plants grow as well as the potential harvesting technique.

What Background Research Do We Need?

- General ideas about agrivoltaics
- What is agrivoltaics
- How can we use agrivoltaics
- What are the some of the best crops people use with agrivoltaics (previous experiments)
- What are practical application of agrivoltaics
- Does it save agricultural space

Variables

These are the variables for this experiment.

Controlled Variables

- The robotic sun
- The atmosphere we grow the crops in
- The amount of sunlight each plant receives

- The same diagram used for each test
- The same amount of soil each plant is grown in

Control variables may vary for each separate experiment.

Manipulated Variables

1. The height of the panel for each test
2. The transparency of the solar panel for each test
3. The type of harvesting technique for each test

Responding Variables

1. Which height of solar panel works best for harvesting and growing
2. Which solar panel has the best transparency for the amount of light that reaches the plants
3. What is the best way to harvest plants while solar panels are on top of them

Time Frame

- Early October to early November:
    - Ella: Robotic sun/building models
    - Ariel: Research
- Mid November to early January:
    - Ella: Tending to the crops
    - Ariel: Observing the early outcomes/starting report
- Late January to school science fair:
    - Coming together and finishing off board and report

Nov 11, 2023 – Today we reviewed measurements for the models and the solar panels. We found a company in the United States that could potentially sell us transparent film made for solar panels and greenhouses. In theory, the film optimizes the sunlight pointed at the solar panels and greenhouses. We decided to email this company about selling us a sample film for us to use on our solar panels.

We measured the size of a single model to be 12 x 8 inches long and decided a single solar panel to be 10 x 6 inches long. We needed enough film for three of the solar panels and therefore asked for 10 x 18 inches of film.

Nov 14, 2024 – We got an email from the company telling us that they would love to send us samples for free!

Dec 3, 2023 – We met remotely today to discuss the project. Certain ideas were brought up such as the type of lighting, and how the robot was going to be programmed. We decided:

- The light that we are going to use should be put on an angle, but should not move up and down to help reduce complexity
- We decided we should start by only experimenting with one test – we decided this test would be the transparency of solar panels. We want to do this because of the fact that we want as many repeated trials as possible. If we have time, we can vary the height of the solar panel
- We are going to continue researching and refining the model and work on installing the light and preparing the models for the initial sets of tests

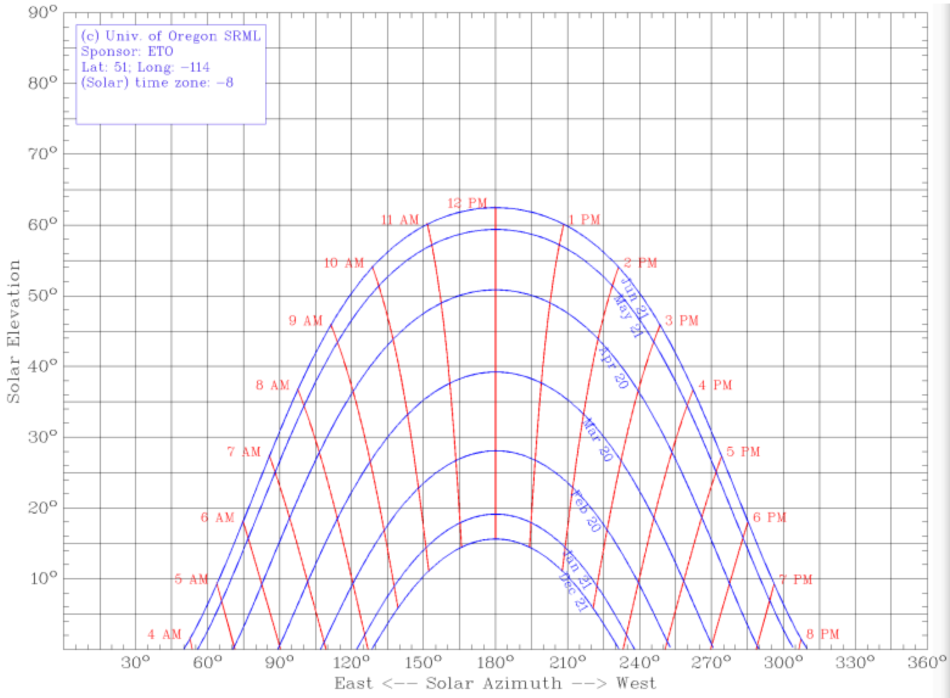
We want to be able to do statistical analysis on the data we collect. To do this we are going to observe the results of many tests and most likely have two responding variables for comparison. The first is going to be the mass of the plants, we can compare how much plant grew in each of the different situations. The second responding variable can be the height of the plant, how tall can the plant grow in different situations.

We want to start experimenting soon so we have time to do more tests later if needed.

Dec 9, 2023 – Materials for the track were gathered from the hardware store. Started to lay out how we will build the light and the models so we can make them in the most effective format. Two planks from the hardware store were cut into three pieces, two being slightly longer than the third, and finally drilled together. This created a track for the robot to run along safely.

Dec 16, 2023 – Ella drilled her Lego robot into 12 by 7 inch wood to make the strongest platform for the "sun". Ella also hung the tracks from for her robot to run across. After hanging the tracks, the robot was run along the planks. We can now begin on the code for the robot. Shelves for the plants were also created.

Dec 17, 2023 – The program for the robot to move across the track was written. The amount of rotations and the length of time between rotations for the "Sun" robot to run along the track was calculated. Using a sun chart with calculations for Calgary and our knowledge of the time frame that mustard is grown we concluded that the robot must run the track over 16 hours to best simulate a summer day.



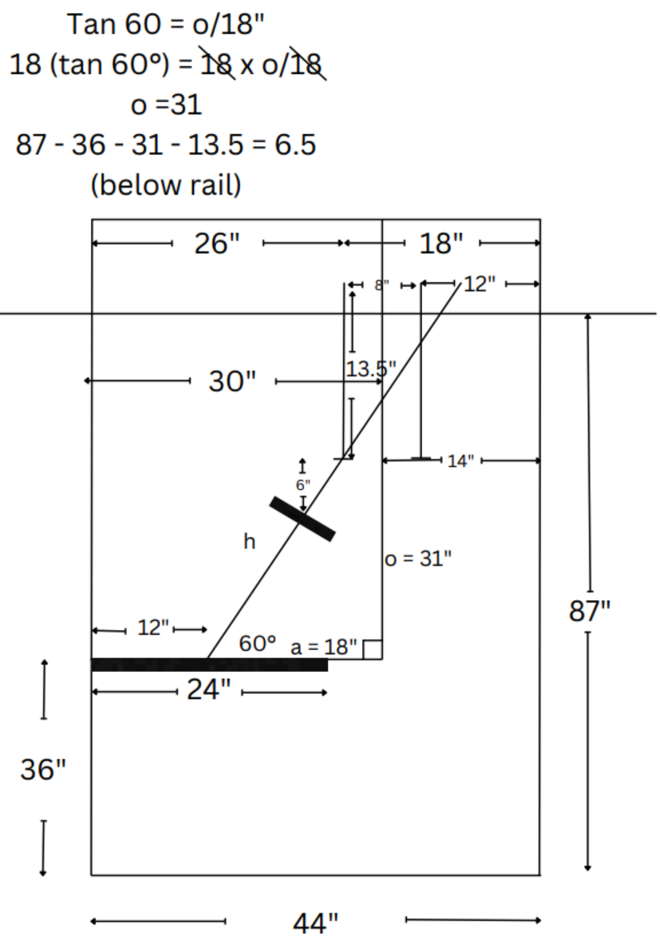
Dec 18, 2023 – Worked on hanging the sun lamp. Trigonometry was used to figure out how high the lamp should be hung.

The optimal growth angle should be 60 degrees, which is the angle of the sun at the peak growing season during the months of May and June.

Since the height of the shelf is 36", and the center of the track (where the center of the lamp would be) is 14" and the width of the space itself is 44" we can conclude that the base of the triangle that we are solving is 18".

The equation to solve is tan 60 = O / 18. Solving for O = 31". This means that the lamp must be 31" above the shelf.

Additional computations were required. The equation 87 (the height of the room) - 36 (the height of the shelf from the ground) - 31 (the height of O) - 13.5 (the height from the roof to the track) = 6.5. This was the height from the track to the center of the lamp.



Dec 26, 2023- Static tests on the robot showed that all of the wheels were running in different directions. Many different forms of the code including new conditions were added, but there continued to be bugs.

Dec 27, 2023 – Ariel and Ella met today to observe and test the robot. We first did more static tests on the robot to make sure all the wheels were running the way they were supposed to. The code points for the motors to run "forwards" along the track for 16 hours. The code then uses a sensor to detect the color red. When it does, the robot moves back to the start of the track and waits 8 hours before repeating the process. A small problem we faced was that the motors would only move if they saw red. Once they did not see red, all the motors would stop moving. To solve this problem we removed the "forever" block in the code, letting the code run once it saw red but continue even if it did not see red afterwards. Another big problem we faced was each motor had its own set of instructions. This meant if one motor saw the color red, then it would start moving backwards. The other motors would never see red and therefore stop. To fix this issue, we made variables to make all the motors stop and start at the same time. This kept good consistency within the movement of all the wheels.

Today we also discussed the timeline for our project and some key things we need to work on to start planting the plants. Below are some notes we took for our time line, when we are starting to plant, and some key issues we need to resolve.

Timeline:

- Start Jun 7 growing

Before than:

- Get solar panels prepared · how tall do they grow? Solar panels = to.
- Water system ready
- Plants ready for growing - plant it
- Soil prepared - put it in
- Robot no errors in code - test until perfect

Solar panels:

- How tall do these plants grow - how do the solar panels need to be proped based on this height? Mustard 3 feet.
- How will the solar panels be securely popped up based on that? Wooden pole/stick.

Water system:

- How can we prepare to water system to, most controllingly, absorb the same amount of water per plant
- Prepare this water system accordingly.

Solutions:

- Top point of solar panels - 28inch above model x
- Bottom point of solarpanels – 2feet above modelx

Jan 2, 2024 – Ella and Ariel met today to go shopping for materials to construct the solar panels and containers to plant the mustard seeds. First we went to the garden store and picked up containers to plant the mustard as well as some extra containers to hold water. We would fill the bottom container with a small amount of water and then dump out the excess water after about 20 min. This would ensure that the plants each have access to the same amount of water and will not rot sitting in the water all day.

After that we went to the hardware store and collected 9 dowels, each at 4 feet to cut and be used as supports for the solar panels, and small connectors to connect the wooden dowels. We also ordered a plastic tube that would be cut and placed on the dowels to hold the solar panels. Then we took a quick trip to Canadian Tire and picked up twelve hockey pucks that would be used as bases for the dowels.

Jan 3 , 2024 – The dowels into the correct measurements, which included cutting 5 of the dowels in half to create ten dowels at two feet to go across and support the solar panels (later we realized that we only needed 8 of these dowels), and 4 dowels were cut into 3 pieces each at one foot, to give us 12 pieces (later we realized we only needed 10 pieces).

Jan 4, 2024 – Ella and Ariel met again today and started to construct the solar panels. We used the dowels and plastic tube pieces cut the day before to create a base for the panels. We strung the tube pieces on the dowels, and later glued the solar panels on to the tube, now the panels could rotate with ease.

Jan 9, 2024 – Each solar panel for the experiment was prepared. This included taping the opaque panels with black tape, taping the UbiGro film onto the film panels and cutting the squares of tape, and putting them onto the semi-transparent panels and the semitransparent with film.

Jan 11, 2024 – Panel assembly was performed today. The fit into the connectors was tight, and so we tried to hammer the dowels into the connectors which damaged the solar panels.

Jan 12, 2024 – Ariel and Ella met together today, and started to place the dirt into the containers. To be as precise as possible we measured ½ cup + 1/8 cup into each container. We also measured the correct amount of water that would be poured into each bin for the mesh under our plants.

Jan 13, 2024 – Reassembly of the panels. The new glue that dried much quicker and more stable. A final test of the robot was conducted. It helped by letting it run a little closer to the red tape so that it would go back to the start. But soon after she went to bed the robot started moving again. It seemed as if not all of the motors sensed the red tape, as they all had separate codes.

Jan 14, 2024 – Debugging continued on the robot. All code needed to be unified to ensure the motors operated at the same time. This was more difficult than expected.

Jan 15, 2024 – After experimenting with many different options to make one code the day before, a solution was discovered. When selecting the motor that you wanted to rotate you could choose multiple motors at the same time. The robot worked as expected.

Jan 16, 2024 – Everything was ready for the experiment. Planting began. Each container was planted with six seeds. The experiment was to begin tomorrow.

Jan 17, 2024 – Each plant was sprayed 3 times and the robot was started. The plants were sprayed again that evening.

Jan 18, 2024 – The p[lants were watered again. Some of the seeds have sprouted. Most plants sprouted are found under the semi-transparent with film panels. Following close behind is the film experiment, then control, semi-transparent and opaque.

Jan 19, 2024 – Ella sprayed the plants this morning and again this evening

Jan 20, 2024 – The robot stopped a little too close to the edge and it had to be started manually. The robot had disconnected from the iPad that the code was on. The code was then downloaded directly to the robot so there would be no need to connect an iPad. Adding blue tape helped out with the accuracy.

The plants were watered in the morning and in the evening.

Jan 21, 2024 – Jan 31, 2024 – The plants were watered in the morning and in the evening.

Feb 1, 2024 – Feb 17, 2024 – Watering of the plants continues on a daily basis. The plants only require one watering per day.

Feb 18, 2024 – Feb 24, 2024 – Plants under the opaque are not developing their leaves. The tallest plants are in the film experiment, but semi-transparent are following close behind. Pieces of paper were added behind the containers to assist in measuring. Pictures of the plants were taken.

Feb 25, 2024 – The plants have been turning slightly yellow.. It was decided that additional nitrogen was required to help supply nutrients that had been used up from the soil.

Feb 26, 2024 – Additional nitrogen was added when the plants were watered. The same amount was added to all of the containers.

Feb 27, 2024 – Feb 29, 2024 – Watering the plants. The nitrogen fertilizer helped improve the quality of the plants.

Mar 1, 2024 – Mar 2, 2024 – A video of the plants was created.

Mar 3, 2024 – Harvesting time!. We spent nine hours harvesting crops which included removing the plants from the containers, washing, measuring, and weighing them. This took all day.

First we measured each container by laying it against a ruler and taking a picture. After, we separated each plant from the dirt and dipped them in water. Making sure to dry them after, we then weighed them 3 times each. Then we counted the amount of crops in each container. This process was completed 180 times in total.

Mar 5, 2024 – The data was statistically analyzed in R using an ANOVA and TukeyHSD test. We found that many of the results were statistically significant. The results showed the most statistical significance when semi-transparent was compared to opaque and control. This suggests that the semi-transparent rejects the null hypothesis which means that the semi-transparent and control means are not the same.

Mar 8, 2024 – We sent an email to Dr. J. Pearce, an expert in agrivoltaics at Western University asking for a meeting to discuss our project

Mar 9, 2024 – We received a reply from Dr. Pearce asking to meet on March 11. The meeting was arranged and questions were prepared for discussion.

Mar 11, 2024 – We met online with Dr. Pearce. We asked him questions about the projects that he was working on. We asked if he had some ideas why the Ubigro film did not have the best results. Dr. Pearce's response was that each plant has a different preference to sunlight, as the Ubigro film directs only red and blue. The mustard may have a slight preference to a different color of light.

Mar 8, 2024 – Mar 14, 2024 – Worked on report and log book. Finished all sections of the report and uploaded the text to the CYSF platform. We were able to draw conclusions that the semi-transparent solar panel had the greatest plant yield.

A video was created for the project, which explains our process of how our project progressed from problem to conclusion.