Seed Germination Study

Jennifer Hoof
Farrington High School

HCPS III Science Standards: SC.BS.1.2–1.6, 2.2, 3.4 & 4.4

Grade Level: 10
Project Time Span: 8–12 weeks (includes 2 half-day field trips)

To The Teacher:
This project is intended for high school biology students. However, the general concepts are fairly basic. The lessons can be altered to make them simpler or more challenging. The fieldtrips are not requirements but they do allow the students to be involved in many parts of the plant propagation process as well as participate in native plant restoration, which exposes them to an environment different from their normal, daily surroundings. If options do not exist for restoration in the natural environment, a site at school or in the local community to out-plant the natives will work.

Goals of the Lesson:
• To practice the scientific method
• To learn about native and non-native plants in Hawai`i through hands-on activities
• To generate a sense of place and understanding of local conservation issues among the students

Student Learning Objectives (Benchmarks):
This lesson addresses Biological Science benchmarks for HCPS III Science Standards:

Scientific Investigation
SC.BS.1.2 Design and safely implement an experiment, including the appropriate use of tools and techniques to organize, analyze, and validate data
SC.BS.1.3 Defend and support conclusions, explanations, and arguments based on logic, scientific knowledge, and evidence from data
SC.BS.1.4 Determine the connection(s) among hypotheses, scientific evidence, and conclusions
SC.BS.1.5 Communicate the components of a scientific investigation, using appropriate techniques
SC.BS.1.6 Engage in and explain the importance of peer review in science

Nature of Science
SC.BS.2.2 Compare the risks and benefits of potential solutions to technological issues
Organisms and the Environment
SC.BS.3.4 Explain dynamic equilibrium in organisms, populations, and ecosystems; explain the effect of equilibrium shifts

Structure and Function in Organisms

SC.BS.4.4 Describe how homeostatic balance occurs in cells and organisms

Resources and Materials:

Materials
- Seeds of native and non-native plants (some suggested species: koa, ma‘o, a‘ali‘i, Ardisia, variety of bean species, weedy plants from school grounds)
- Dissecting Microscopes
- Nail clippers
- Files
- Sandpaper
- Beakers
- Hot plates
- Coffee filters
- Potting Soil
- Germination Trays
- Computer and Internet access equipped with versions of Microsoft Word and Excel
- Appendices A–K are student handouts for all activities.

Book

Video

Websites
- Hector Perez, University of Hawaii GK–12 Fellow, Conservation Horticulture: http://www.hawaii.edu/gk-12/evolution/hector/
- National Geographic’s Strange Days on Planet Earth http://www.pbs.org/strangedays/index_flash.html

Instructional Procedures & Student Learning Activities:
Day 1: Introduction to invasive species
• Introduce terms: Native, Endemic, Indigenous, Non-native, Invasive, Exotic, Naturalized
• Read and discuss article from The Star Bulletin: Special Report: Miconia Invasion (Appendix A)
• Show segments from National Geographic's Strange Days on Planet Earth part I: Invaders. Specifically, show Miconia segment
  - The video is relevant to Hawai’i as one segment shows the fight against Miconia on the Big Island of Hawai’i (Appendix B)
  - Students answer the questions on the worksheet related to the information they see in the video

Day 2: Experimental Design
• Briefly Review video
• Discuss reasons why some non-native species become invasive. Invite and/or guide students to come up with the possibility that non-native species may germinate more quickly or have a higher percentage of germination than native plants.
  - An ability to germinate faster (and/or have higher percentage of viable seeds) increases competitive ability for space, nutrients, light, and water
• Brainstorm and pick a research question for the class to ask related to germination of native and non-native seeds.
• Then, students write a hypothesis addressing the research question (Appendices G and H)
• Brainstorm a procedure to address research question.
  - Show students available materials then have groups design experiment (Appendix H) to look at germination of native and non-native plants
• Explain to students that not only will they be germinating native seeds, they will also go on fieldtrips to clear an area of non-native and invasive plants and replace them with the native seedlings they germinate. This activity allows students to not just talk about what is going on in our ecosystems, but to actually make a positive change in the make-up of the Hawaiian forests. Students will have “stake” in the forest, work outside, and begin being able to identify native and non-native species. The first fieldtrip will involve becoming familiar with the location, identifying the plants at the site, and eradicating the non-native species.

Day 3: Research native and non-native species
• Students use Internet and library sources to research the native and non-native plants available from teacher for the germination experiment

Day 4–5: Seed Germination
• Students practice learning about germination rates and identifying parts of a germinating seed with different types of generic seeds (ex. dried beans, herbs, vegetables).
• This activity is best started on a Friday and checked for results on the next Monday
• Students should learn from their experiments that not all seeds germinate at the same rate or at all under "ideal" conditions. See Appendix E

Day 6: Seed Dormancy
• When students collect data and notice not all seeds have germinated discuss possible reasons
• Introduce seed dormancy. See Appendix F
• Seed dormancy prevents germination for many reasons including season, timing with pollinators or to prevent herbivory.

Day 7–8: Seed Scarification
• Seed Scarification is how conservation horticulturists experiment with ways to induce germination of native plants to increase the populations that get replanted in the wild.
• Students can experiment with different types of scarification. See Appendix F

Day 9
• Discuss the rubric for the experiment they will carry out (Appendix C).
• Now that students have learned about dormancy, they may decide to modify their methods (Appendix H) to include seed scarification as a variable (ex. scarification vs. no scarification affect on germination rate).
• Allow then time in class to discuss and modify method before beginning experiment the following day

Day 10–31
• Set up experiment based on student-designed method
• Collect data daily on number of germinated seeds for at least three weeks. Appendix I is a data table that all groups in all sections can combine their data for data analysis on Excel (Appendix J)
• During this time, take students on 1st fieldtrip to out-planting site to survey the area for native and non-native species as well as to clear an area for the native seedling planting

Day 32–33
• Use Microsoft Excel to make data tables and graphs

Day 34
• In order to make the data meaningful, students need to discuss the results, draw conclusions, and provide suggestions for future research (Appendix K).

Day 35: Wait several weeks (at least 3, more if time permits to allow seedlings to grow)
• Finally, students will take their 2nd fieldtrip to out-plant their native seedlings. If the seedlings are not large enough and suitable for out-planting, natives can be purchased at a local nursery to replace or supplement the seedlings. Then, the seedlings can be kept in the classroom until there are large enough to out-plant and serve as an identification garden on campus.

Assessment:
• Teacher Observations & Communications with student
• Components of Lab Report
• Worksheets

Extension:
• Address the traditional Hawaiian Moon planting cycle when deciding when to sow the seeds
• Bring kupuna from community to discuss traditional uses of plants
• Have students learn oral history of area in terms of what the natural environment looked like and how people interacted with it many years ago (forest vegetation and activity)

Evaluation of Lesson:
**What worked well**
• The fact that the procedure was simple and attainable made designing an experiment seem attainable to the students. They enjoyed feeling as if they were helping the environment by growing native plants to out-plant in the forest. It helped develop the sense of place in them.

**What would I do differently**
• I would allow time for the students to modify their procedures and repeat the germination experiment based on the results (which germinated and which did not) and their conclusions of the effectiveness of particular scarification techniques.

Notes:
This lesson also addresses HCPS III standards in Social Studies:
**Benchmark SS.9MHH.1.1** Describe the multiple social, political, and economic causes and effects of change in modern Hawaii

**Benchmark SS.9MHH.3.9** Analyze significant contemporary issues that influence present day Hawaii, such as the Hawaiian Renaissance, the sovereignty movement, current land issues, and the influx of new immigrant groups
The Green cancer spreads
By Gary T. Kubota: gkubota@starbulletin.com

HANA, Maui >> A single miconia plant is like an environmental time bomb.

Once it reaches maturity in five years, miconia calvescens is capable of bearing several million seeds annually. The seeds are spread by the wind, vehicle tires, the bottoms of shoes, and fruit-eating pigs and birds. More than $1 million is spent each year on Maui and the Big Island to fight this one plant, and the cost is expected to rise; some say it would take $49 million to get rid of miconia.

In Kawaipapa Valley mauka of Hana town, the large leaves of miconia trees are rising like an explosion of green mushrooms to dominate a native ohia forest. "This whole valley is all infested," said Jack Peterson, whose Maui Invasive Species Committee is trying to eradicate the plant. "There are thousands of little ones."

Fighting miconia has been compared to battling an out-of-control forest fire. Crews try to kill the plant before it reaches maturity. But the infestation is jumping to other areas, including Haleakala National Park at Kipahulu.

In a helicopter, Peterson and his crew mark the location of scattered growths of miconia along the sides of ridges several The crew will eventually return by helicopter to either spray an herbicide on the plants or rappel down to cut and poison the trees.

Within the main infestation between Kawaipapa and the Hana landfill, a bulldozer has cleared more than 10 miles of four-wheel-drive road to allow a five-person state crew access to kill the miconia. Since 1996, the crew has been pulling out saplings or cutting and poisoning the trees within a 2,000-acre area above Hana town. The crew has killed as many as 50,000 plants in a single day, made easier in areas where a mature tree has been cut and the canopy is open to sunlight. Some seeds have been known to germinate six years after entering the soil.

**Alien plant invader** Maui native forest birds and plants are facing a major threat of extinction from what the Tahitians refer to as "le cancer vert," or the green cancer. Scientists say the miconia will do more damage than any alien species, if left unchecked.

In Tahiti, where the miconia has taken over an estimated 70 percent of the native forest, or 196,600 acres in 64 years, islanders are reeling from the environmental consequences.

"This small tree is undoubtedly the worst alien plant invader in tropical islands worldwide," said Jean-Yves Meyer, who worked as a scientist fighting the miconia in Tahiti for several years.

Miconia is unlike many alien species that grow side by side with native plants. A native of South America, the plant grows up to 50 feet tall with leaves more than a foot and a half wide and close
to three feet long. Because its roots are shallow, mountain slopes occupied by it are susceptible to landslides. Miconia can block sunlight to other plants, effectively killing them or stunting their growth.

Meyer said 50 to 75 plant species found only in Tahiti are directly threatened by miconia and several have become extinct, especially low-lying native shrubs similar to those found in Hawaii. Meyer said native Tahitians have difficulty finding wild bananas in the forests, a traditional staple in their diet, or wild apple and orange trees. Trees used for building canoes are becoming scarce. Miconia also has degraded watershed areas, promoting erosion and landslides.

**The threat in Hawaii**  Miconia infestations span an estimated 20,000 acres on the Big Island and 12,000 acres in East Maui. Some plants have been found but controlled along the Wailua River on Kauai and in Wahiawa and the valleys of Manoa, Nuuanu and Kalihi on Oahu. On Maui, at stake is the integrity of the 100,000-acre East Maui watershed, which provides irrigation and drinking water for thousands of households along the slopes of Haleakala. It threatens native wildlife havens at Honaunau and Kahaualea on the Big Island and East Maui's Hanawi Natural Area Reserve, which has the highest number and density of endangered forest birds in the state. The reserve is home to the po'ouli, the Maui parrotbill and four other rare forest birds, as well as 18 rare plants, various snail species and an unknown number of native insects, according to the state. Wildlife advocates point out that without an effective miconia control or eradication program, government officials will have wasted millions of dollars in maintaining wildlife habitats and raising endangered bird species to allow them to return to the wilderness. "It will eventually crowd out other plants including native and alien species," said Donald Reeser, the superintendent at Haleakala National Park. "All the work we've been doing in areas, fencing out pigs. If we can't get rid of it, all that work is wasted."

**Need more funding**  Federal park and forestry officials say more funding is needed for Maui and the Big Island to reduce the infestation, rather than control it. They say more money is needed to find biological controls for the plant. "All we're doing is making the minimal payment so our minimum balance is continuing to grow," said Duane Nelson, a forest health specialist with the U.S. Department of Agriculture.

Wildlife advocates note that while 26 percent of the endangered and threatened species in the United States are in Hawaii, less than 6 percent of the federal money for preserving them is spent in the islands. The total budget statewide for miconia eradication is a fraction of what groups say they need.

Invasive species specialists on the Big Island and Maui estimate the cost of miconia eradication would amount to $7 million annually for at least seven years -- $4 million for the Big Island and $3 million for Maui. The total budget for both groups decreased by $69,000 to $1.01 million this year, mainly because of a drop in financial support from the state Legislature. The state lawmakers decreased funding for miconia reduction to $400,000 this year from $500,000 last year. The lack of government support has prompted the groups to seek out donations from nonprofit organizations and explore other means of generating revenues.
Appendix B: Invaders
Strange Days on Planet Earth

Name: __________________________

Background
As you may know, invasive species can cause a great deal of damage to the ecosystems they invade. Today, you will learn about invasive species in places like Lake Victoria in Uganda and the Big Island of Hawai‘i. Think critically while you watch the video and answer the questions below (the answers may not be word-for-word from the video).

Questions
1. Explain and give examples of some effects that invasive species have on human health, food chains, the economy, and the environment.

2. Explain how Miconia arrived to Hawai‘i, the characteristics that make it invasive, and why it is harmful to Hawai‘i’s ecosystems (what it does/its interactions with the environment).

3. Bio-control involves the use of specially chosen living organisms to control pest/invasive species. Explain why it is important to understand the biology of the living organisms before bringing them into habitats? Give a successful and an unsuccessful example from the video.

4. As the video mentioned, most things marketed as “Hawaiian” (ex. Macadamia nuts, Pineapple, Sugarcane, etc.) are not actually native species in Hawai‘i.
   a. Has the information presented changed your understanding of native species in Hawai‘i? Explain.

   b. Can you think of any other species that might also be mistaken for native?
Appendix C

NATIVE & NON-NATIVE PLANT GERMINATION EXPERIMENT

Design an experiment to answer the following research problem:

"Do non-native species have higher germination rates than native species?"

The experiment will be conducted as a group. However, your final report is an INDIVIDUAL grade and must contain the items in the rubric below:

<table>
<thead>
<tr>
<th>Exceeds</th>
<th>Meets</th>
<th>Approaching</th>
<th>Does not meet</th>
<th>Pts.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title</td>
<td>Included, descriptive and concise title that give you an idea of what the project is about</td>
<td>Included, related to experiment, but could be more descriptive</td>
<td>Included, but not descriptive of experiment</td>
<td>Not included</td>
</tr>
<tr>
<td>Literature Search</td>
<td>Contains highly detailed and clear descriptions about the native and non-native plants used by at least 2 groups in class. Information is from at least 4 credible sources. Information is clearly written in student’s own words and evident student understands terminology. Student follows format on worksheet.</td>
<td>Contains detailed descriptions about the native and non-native plants used by at least 2 groups in class. Information is from at least 2 credible sources. Information is written in student’s own words.</td>
<td>Contains brief descriptions about the native and non-native plants used by 1 group in class. Information is from at least 2 credible sources. Information is written in student’s own words.</td>
<td>Not included</td>
</tr>
<tr>
<td>Research Problem</td>
<td>“Do non-native species have higher germination rates than native species?” is stated.</td>
<td>Stated, based on research problem, “Because” statement is not scientifically grounded</td>
<td>Stated, but no “because” statement is given</td>
<td>Not included</td>
</tr>
<tr>
<td>Hypothesis</td>
<td>Clearly stated, based on the research problem, includes a reasonable and scientific “Because” statement</td>
<td>Two plant species are investigated, reasonable # of trials are used, written in past tense and paragraph form, detailed, understandable, and repeatable</td>
<td>Two plant species are investigated, inadequate # of trials, written in past tense and paragraph form, missing some essential details and description, thus is not repeatable</td>
<td>Two species are investigated, inadequate # trials, not written in past tense and paragraph form, not repeatable OR missing</td>
</tr>
<tr>
<td>Materials &amp; Methods (procedure)</td>
<td>At least two plant species are investigated, reasonable # of trials are used, written in past tense and paragraph form, detailed, understandable, and repeatable</td>
<td>Data tables created by Excel Tables have captions concisely describing the information in tables Accurately labeled sketches of the seeds and seedlings are of high quality</td>
<td>Data tables created by Excel Tables have captions describing the tables Labeled sketches of the seeds and seedlings are of medium quality</td>
<td>Data tables created by hand and lack captions Sketches of the seeds and seedlings are of low quality OR Data and sketches are missing</td>
</tr>
<tr>
<td>Data &amp; Sketches</td>
<td>Results state the data.</td>
<td>Results state the data.</td>
<td>Results missing or incomplete</td>
<td></td>
</tr>
<tr>
<td>Results</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discussion &amp; Conclusion</td>
<td>References</td>
<td>General</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>------------</td>
<td>---------</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>The results section includes:</strong> High quality graphs of class data with accurate captions</td>
<td>Information obtained from resources is referenced using proper format within the paper</td>
<td>All sections are present and in proper order</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statistical analysis of the data collected</td>
<td>Bibliography section at the end of the whole report contains all material referenced and is properly formatted</td>
<td>No grammar or spelling errors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO interpretation of the results is included (save for the discussion)</td>
<td></td>
<td>Report is typed OR legibly handwritten in ink</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>The discussion includes:</strong></td>
<td></td>
<td><strong>General</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thorough interpretation of the graphs and the statistics and makes sense of the data for the reader</td>
<td>Information is referenced using proper format within the paper</td>
<td>All sections are present and in order</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparison of hypothesis and results</td>
<td>Bibliography section at the end of the whole report contains all material referenced and most of it is properly formatted</td>
<td>A few grammatical or spelling errors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Possible errors</td>
<td></td>
<td>Report is typed OR legibly handwritten in ink</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The conclusion relates the experiment to “The Big Picture” and addresses the following points thoughtfully and scientifically: Relationship of results and background information in literature search</td>
<td>Information is referenced improperly or not consistently within the paper</td>
<td>Several grammatical or spelling errors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of results and meaningfulness to people outside of your science class</td>
<td>Bibliography section at the end of the whole report missing references and is improperly formatted</td>
<td>Report is legibly handwritten in ink</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suggestions for future research or actions to take</td>
<td></td>
<td>Missing sections or out of order</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discussion Includes: Reasonable <strong>Discussion Includes: Fair</strong> Interpretation of the graphs and the statistics and makes sense of the data for the reader</td>
<td>Discussion Includes: Poor Interpretation of graphs and statistics and does not make sense of data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comparison of hypothesis and results</td>
<td>Minimal discussion of hypothesis, results, and errors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Possible errors</td>
<td>Conclusion not related to “The Big Picture” and fails to see relationship of results and background information as well as meaning of research</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conclusion relates the experiment to “The Big Picture” and addresses: Relationship of results and background information in literature search</td>
<td></td>
<td>Difficult to understand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of results and meaningfulness to people outside of your science class</td>
<td></td>
<td>Handwritten</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Don’t let the rubric overwhelm you. We will work on this piece by piece. However, do not let yourself fall behind as it will be difficult to make up all the work right before it is due. Your group is relying on you to participate and stay on task.**
Appendix D: Seed Germination

Name: ____________________________

Background

From previous experiences, you probably know that plants come from seeds. Seeds are very remarkable. Inside the seed is an embryo packed with stored chemical energy to power the young seedling until it can capture its own energy from the sun by the process of photosynthesis. Proper timing of germination (the breaking of the dormancy) is important to the success of the young seedling. For instance, seeds from the milkweed plant are produced in late summer and fall but they lay dormant until the spring. This is because seeds often respond to signals in the environment in order to germinate at appropriate times.

Many environmental factors can affect seed germination. Light intensity, day length, night length, light color, water, water quality, gravity, crowding, temperature, nearby plants (by chemical agents), genetics, oxygen availability, seed condition, seed age, seed coat condition, and seed size among others can affect seed germination.

In order to germinate, a seed has to absorb lots of water. In nature, seeds absorb this water from the soil. In this experiment, we will simply use wet paper towels as the water source so that we can see the germination process occur.

Part A.

Germinate seeds by following the procedure below.

1. Obtain 20 seeds, a paper towel, and plastic wrap
2. Moisten the paper towel and place the seeds on it, spaced evenly
3. Roll up the paper towel
4. Cover it with plastic wrap and label with your group’s name and period and set aside
5. Record the type of seeds used: ____________________________
6. Predict the number of seeds that will germinate over 48 hours: _____________
7. Check the seeds after 48 hours for germination
8. Record data for # seeds, # germinated, and % germination in the table below

<table>
<thead>
<tr>
<th>Group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of seed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total # of seeds</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total # of seeds germinated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage (%) of seeds germinated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
9. Graph the percentage of germination per group

<table>
<thead>
<tr>
<th>% Seeds Germinated</th>
<th>Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Part B.
Dissect one of your germinated seeds. Draw and label the part of the seed (cotyledons, hilum, seed coat, plumule, radicle, embryonic leaves) in the space below.

Analysis Questions
1. Hypothesize why all your seeds may not have germinated.

2. How might the number of seeds that germinate quickly relate to a species ability to be invasive?

3. How might slow germinating native plants affect a culture (ex. handcrafts, kapu system)?
Appendix E: Seed Dormancy

Name: __________________________

Background
In the last activity you germinated seeds. You saw that not all seeds germinate at the same rate. However, many seeds may not germinate, EVEN IF the ideal conditions exist (like the Petri dish with water). Some seeds go through dormancy, a state of decreased metabolism, just like animals such as the polar bear does in winter. Seed diversity and dormancy are interesting topics that we will explore in these activities.

Part A. Seed Diversity
1. Observe the package of seeds at your table
2. Find similarities and differences between the seeds and list them in the space below
3. Additionally, sketch each seed in the space below

<table>
<thead>
<tr>
<th>Seed Comparison</th>
<th>Sketch of Seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Similarities</td>
<td>Differences</td>
</tr>
</tbody>
</table>

Part B. Seed Dormancy
Fill in the four sections about seed dormancy of this chart based on the statement in each box

#1: WHAT
#2: WHY
#3: HOW IT WORKS
#4: WHAT IF
Part C. Types of Dormancy Found in Seeds

Read the following information (source: Hector Perez: http://www.hawaii.edu/gk-12/evolution/hector/kanuikapono/7-11/SeedDormancy7-11.pdf) and answer the questions.

Just as seeds are diverse in the way they look, there are five different types of seed dormancy. Remember, seed dormancy is a reduction in metabolism in which seeds resist germination even in ideal environmental conditions.

Physical dormancy is usually a characteristic of seeds with hard, thick seed coats. Hard, thick seed coats usually do not allow water to reach the embryo. And, even when some water does pass through the seed coat, some sort of feature of the seed coat still does not allow the embryo to germinate. Seeds that possess physical dormancy may stay dormant for a LONG time. Some physically dormant seeds can even resist damage from very high temperatures caused by fires!

Seeds are said to be physiologically dormant when the normal life processes within an embryo are delayed. Many different mechanisms can cause seeds to be physiologically dormant. For example, some seeds require light to trigger germination. If those particular seeds are held in darkness, they cannot germinate. Other seeds have growth inhibitors that can only be "turned off" by growth stimulants. Then, the seeds will germinate.

Morphological dormancy is another form of seed dormancy. This occurs when seeds have embryos that are not fully developed when they leave the fruit or plant. In other words, the embryo needs time to grow inside the seed before it can germinate. *Pritchardia limahuliensis*, a species of palm found only on Kaua’i, is a good example of a plant with morphologically dormant seeds.

Mechanical dormancy occurs in seeds that cannot germinate because some part of the fruit coat prohibits germination. Sometimes structures that surround seeds, like wings, are enough to block germination.

Finally, chemical dormancy occurs when chemicals in the fruit coat and seed coat block germination. Unless the chemicals are washed away or inactivated, germination cannot occur. Seeds from desert plants have chemical dormancy. These seeds must wait until sufficient rains wash the chemicals away.

And, if all those mechanisms are not enough to prevent seeds from germinating, some seeds can have multiple dormancy mechanisms!

Analysis Questions

1. Koa seeds have hard coats and gardeners often soak the seeds in water before planting.
   a. State the type of dormancy Koa seeds have: __ __ __ __
   b. Hypothesize what soaking might do to the seeds

2. Hypothesize the benefit of having more than one kind of dormancy.

3. Australian Aborigines have used fire to manage their natural resources for thousands of years. It has been shown that important food plants increase in number after a fire. For example, *Solanum vescumm* was an important fruit for the Aborigines in Gippsland. In the first year after a fire, it is abundant, arising from the seedbank in the soil. It thrives only briefly after a fire, and regular burning is necessary for continued fruit production.

How might the information about the Aborigines be related to seed scarification and the ecological knowledge of the native people?
Appendix F: Seed Scarification

Name: __________________________

Source: Hector Perez: http://www.hawai.ledu/gk-12/evolution/hector/

Background

Hard seeds are amazing. Some are so hard you can hit them with a hammer, run them over with a truck or squeeze them in pliers and they still won't break! Others can be scratched with sandpaper or placed in boiling water only to have a few seeds germinate. The reason for this toughness is the seed coat. For instance, the seed coat may be several layers thick or made of a few layers that are packed very tightly.

In nature, seed dormancy is beneficial. For example, seeds that germinate in a drought will die from lack of water. So, waiting until the rains come is a positive adaptation for certain plants.

However, because of these natural germination inhibitors, horticultural scientists conduct research to determine the best techniques to germinate the most seeds. This type of research benefits businesses and people who buy plants--they do not have to wait months or even years for their seeds to germinate!

In the field of conservation, scientists (Conservation Horticulturists) do research on endangered and threatened plant species. The knowledge they gain about germination helps us grow endangered plants more rapidly than we could before, so we can plant them back in their natural environments. Hopefully, the plants will establish and flourish like they did before they became endangered with human help in germination.

Today, we will practice treatments to make hard seeds germinate. These treatments work by damaging the seed coat. This is called scarification. Seeds can be scarified in several ways. For example, seeds can be clipped, sanded, and heated.

Problem

Which seed scarification method is the best for each of the species (chosen by teacher)?

Hypothesis

Procedure

• Read through the procedures below for each method of scarification
• Test the species assigned to your group using each scarification method. You will be using seeds with hard seed coats, which prevent germination
• Sow seeds in Petri dishes with sand, moist paper towel, or in soil (what ever option is available)
• Collect data on # of seeds that germinated after 48 hours for each treatment

Hot Water Method

1. Fill a beaker about \( \frac{1}{2} \) way with water
2. Heat the water until it boils
3. Place 5 seeds in a coffee filter
4. Repeat step 3 with 2 other bags
5. Seal the filter by tying the opening together with a string (it should look like a little pouch)
6. Remove the container from the heat and place your bag of seeds in the water
7. Remove one bag from the water after 30 sec.
8. Allow the other two bags to remain in the water (one for 30sec more and one for 1 min more)
9. After treating the seeds in water, sow the seeds and observe germination rate
10. Record the treatments and the germination rates in the data table below

**Sandpaper Method**
1. Obtain sandpapers of three different grits (two pieces each)
2. Place 5 seeds in between two sheets of sandpaper with the same grit and rub
3. After treating all three sets of seeds, sow the seeds and observe germination rate.
4. Record the treatments and the germination rates in the data table below

**Filing Method**
1. Obtain a file and 15 seeds
2. File down 5 replications of seeds (three different treatments total) varying # of times or in different locations (circle the one you chose). Then use the space below to describe location or # filings: ____________
3. After treating each set of seeds, sow the seeds and observe the germination rate
4. Record the treatments and the germination rates in the data table below

**Clipping Method**
1. Obtain large fingernail clippers and 15 seeds
2. Use the fingernail clippers to clip off one piece of seed coat for 5 seeds
3. Then, clip two pieces of seed coat from the second set of 5 seeds, and three pieces for the last group of seeds. Make sure not to damage the embryo.
4. After treating each set of seeds, sow the seeds and observe the germination rate
5. Record the treatments and the germination rates in the data table below

**Class Data Table**

<table>
<thead>
<tr>
<th># Seeds germinated</th>
<th>Group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hot Water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sandpaper</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Filing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clipping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Analysis Questions**
1. From your own data, what treatment amount gave the highest germination rate?

2. From the class data, which scarification treatment appeared to be the best for this species? Explain.

3. Another seed scarification method involves dipping seeds in concentrated acid. Hypothesize what natural process scientists try to mimic by using this technique.
Appendix G: Web Quest

Part A. Plant Species

Procedure
1. Record the name of the plant species your group chose for the germination experiment in the table below.
2. Search the Internet for information about each species
3. Fill in the table below with the information you find.

<table>
<thead>
<tr>
<th>Species 1</th>
<th>Species 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scientific Name:</strong></td>
<td><strong>Scientific Name:</strong></td>
</tr>
<tr>
<td><strong>Common Name:</strong></td>
<td><strong>Common Name:</strong></td>
</tr>
<tr>
<td><strong>Native to:</strong></td>
<td><strong>Native to:</strong></td>
</tr>
<tr>
<td><strong>Climates/Habitats found in:</strong></td>
<td><strong>Climates/Habitats found in:</strong></td>
</tr>
<tr>
<td><strong>Endangered? (Y or N):</strong></td>
<td><strong>Endangered? (Y or N):</strong></td>
</tr>
<tr>
<td><strong>Invasive? (Y or N):</strong></td>
<td><strong>Invasive? (Y or N):</strong></td>
</tr>
<tr>
<td><strong>Dispersal Method:</strong></td>
<td><strong>Dispersal Method:</strong></td>
</tr>
<tr>
<td><strong>Interesting Facts:</strong></td>
<td><strong>Interesting Facts:</strong></td>
</tr>
<tr>
<td><strong>Cultural Significance:</strong></td>
<td><strong>Cultural Significance:</strong></td>
</tr>
<tr>
<td><strong>Conservation Efforts/Information:</strong></td>
<td><strong>Conservation Efforts/Information:</strong></td>
</tr>
<tr>
<td><strong>Species 3</strong></td>
<td><strong>Species 4</strong></td>
</tr>
<tr>
<td>---------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Scientific Name:</td>
<td>Scientific Name:</td>
</tr>
<tr>
<td>Common Name:</td>
<td>Common Name:</td>
</tr>
<tr>
<td>Native to:</td>
<td>Native to:</td>
</tr>
<tr>
<td>Climates/Habitats found in:</td>
<td>Climates/Habitats found in:</td>
</tr>
<tr>
<td>Endangered? (Y or N):</td>
<td>Endangered? (Y or N):</td>
</tr>
<tr>
<td>Invasive? (Y or N):</td>
<td>Invasive? (Y or N):</td>
</tr>
<tr>
<td>Dispersal Method:</td>
<td>Dispersal Method:</td>
</tr>
<tr>
<td>Interesting Facts:</td>
<td>Interesting Facts:</td>
</tr>
<tr>
<td>Cultural Significance:</td>
<td>Cultural Significance:</td>
</tr>
<tr>
<td>Conservation Efforts/Information:</td>
<td>Conservation Efforts/Information:</td>
</tr>
</tbody>
</table>
Appendix H: Computer Lab Preparation Day
Name: __________________________

Tomorrow you will go to the computer lab to type the following items for your Germination Experiment report:

• Title
• Plant Species background
• Research Problem
• Hypothesis
• Materials and Methods

Today, we need to finalize the information and put them in the correct format.

**Sections**

1. **Title Page**
   a. Write a descriptive and brief title that gives the reader a clear understanding of what type of research was conducted. This will go on its own page.
      
      YOUR TITLE: __________________________

   b. Your name: __________________________

   c. Science organization (Your type of science class and school):

2. **Plant Species Background, Research Problem, Hypothesis**
   a. After your biodiversity research paper, which gives readers a firm understanding of biodiversity, Hawaii and its habitats, and native and invasive species, you will include another paragraph. The next paragraph will include the information you researched on the two types of plants you grew AND the research problem AND the hypothesis

   b. **Paragraph I:**
      i. Discuss the native and non-native plants you researched on the Internet (if you need more space, use a separate sheet).

         ______________________________________
         ______________________________________
         ______________________________________
         ______________________________________
         ______________________________________
         ______________________________________
         ______________________________________
         ______________________________________
         ______________________________________

   c. **Paragraph II:**
i. Write a transition from information to your research problem. For example: “As mentioned in the research, native species often do not compete well with invasive species for ...... and......because.............and I wanted to know a faster germination rate of non-native species related to their competitive edge ...........”

ii. Sentence 6: The research problem:
“So I designed an experiment to ask...(insert research problem).”

iii. Sentence 7: Your Hypothesis
“I hypothesized that......because......”

Now, use the space below to put all the sentences together into one complete paragraph:
Appendix I: Materials & Methods

Name: __________________________

Background
In scientific literature (ex. lab reports, journal articles), the step-by-step procedure used in experiments has a different name and format. It is called the “Materials and Method” section and it is written in paragraph form and past-tense (did, went, added, etc.). And, you are a real scientist and designed your own experiment to compare the germination rates of several species of plants. So, your final lab report must contain your procedure written in the proper materials and methods format.

Procedure
Before you begin writing your materials and methods, examine the sample materials and methods sections (below) for a plant growth study:

SAMPLE A: In preparing the pots for the plants, we added soil to the pots until the soil was 2.5cm from the top. The pots were labeled with their treatments: Control (water), Vermicast, and Miracle-Gro. Five red bean seeds were obtained for each treatment. Then, we used an electric scale to determine the total mass (in grams) of each set of five seeds used for each treatment. Then, the seeds were evenly spaced on top of the soil. We watered each pot until water leaked from the bottom of the pot, which indicated the soil was saturated with water. The pots were kept in watering trays that provided a constant supply of water. Once the pots were in place, the Vermicast and Miracle-Gro treatments were sprayed with 8 squirts of their respective fertilizers. The treatments were applied once a week for eight weeks. Plant growth data was obtained weekly by measuring average: plant height, stem diameter, leaf surface area, and number of leaves for each treatment. At the conclusion of the experiment, the soil was removed from the plants and the mass of plants from each treatment was found using the same electric scale.

SAMPLE B: We added soil to the three pots. Seeds were obtained for each treatment. Then, we determine the total mass (in grams) of each set of seeds used for each treatment. We watered each pot until water leaked from the bottom of the pot, which indicated the soil was saturated with water. Once the pots were in place, the Vermicast and Miracle-Gro treatments were sprayed with 8 squirts of fertilizer. The treatments were applied once a week. Plant growth data was obtained by measuring average: plant height, stem diameter, leaf surface area, and number of leaves for each treatment. At the conclusion of the experiment, the mass of each plant was found.

1. Compare and critique the samples for content. Is there enough detail? Too much? Are the methods from each sample repeatable? Explain.
2. Then, write your group’s step-by-step procedure in present tense in the space below. Include enough detail and information so your experiment can be repeated by someone who knows nothing about what you are doing.

Step-by-Step Procedure to address the question: “Do non-native species have higher germination rates than native species?”

STEPS:

3. Now, use the samples as a model to help you convert your steps listed above into past-tense and paragraph form. Remember, there is no exact or correct way to write a procedure (each group will be slightly different) as long as it is repeatable and the information is complete.

MATERIALS & METHODS:
### Appendix J

#### PERIOD

<table>
<thead>
<tr>
<th>Species</th>
<th>Gr 1</th>
<th>Gr 2</th>
<th>Gr 3</th>
<th>Gr 4</th>
<th>Gr 5</th>
<th>Gr 6</th>
<th>Gr 7</th>
<th>Gr 8</th>
</tr>
</thead>
<tbody>
<tr>
<td># Germinated</td>
<td>DAY 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total germinated</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Surviving</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PERIOD</th>
<th>Gr 1</th>
<th>Gr 2</th>
<th>Gr 3</th>
<th>Gr 4</th>
<th>Gr 5</th>
<th>Gr 6</th>
<th>Gr 7</th>
<th>Gr 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># Germinated</td>
<td>DAY 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total germinated</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Surviving</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix K: Data Analysis
Name: ______________________

Background
Tomorrow you will go to the computer lab to analyze the germination rate data of the seeds from period 1 and 4. You will use Excel to analyze the data and make graphs. Today you will:

- Organize data
- Calculate rate
- Learn about Excel: entering data, analyzing data & making graphs

PART A. Computer Lab Preparation
1. Look at all data from both classes and find any groups that did the same plants.
2. Find the average number of germinated seeds for each day for all the plants that had more than one replication.
   a. For example, if several groups did Mung bean, then for each day add the number of seeds germinated for all groups and divide by the number of groups.
   - What is the average number of Mung beans that germinated on Day 3?

<table>
<thead>
<tr>
<th>Species</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mung Bean</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Day 1</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

\[
\frac{2 + 1 + 3}{3} = \frac{2}{2} = \frac{2}{3} \text{ beans}
\]

3. Then organize the data into native and non-native by putting a * next to all native species. You will be making separate data tables on the computer for native and non-native. It will be a good idea to divide the task among group members (two do native and two do non-native)
4. You will make a data table and a graph of these data on Excel in the computer lab tomorrow. To prepare for the task, determine the following before going to the lab.

DATA TABLES
CAPTION (explains contents of the tables): Native: ______________________
Non-native: ______________________

GRAPHS
Title: ______________________
X-axis Label: ______________________
X-axis Unit: ______________________
Y-axis Label: ______________________
Y-axis unit: ______________________

139
5. Watch the tutorial in class on how to use Excel to make data tables and graphs.

PART B.
Computer Lab
1. Locate the icon for EXCEL on the desktop

2. A spreadsheet will open. Vertical columns are identified by alphabets and horizontal rows are numbered. The intersection of a column and a row is called a CELL. For example, your cursor should be in the cell A1 when you first start. You will be entering your data into cells

3. In cell B1 enter the word “Native Species”

4. In cell A2 enter the word “Day”

5. In column A, starting with cell A3, enter the days: 1, 2, 3, etc. until the last day of your data collection

6. In row 2, starting in cell B2 enter the names of all the native species used. Make sure to only enter each species once as you have averaged the data yesterday

7. Highlight the cells in row 2 containing “day” and the species names. Locate the word “format” on the top of the screen. Click Format and “cell.” Then, click “alignment” and change the orientation of the text to be 90 degrees reading bottom to top.

8. In each column enter the number of germinated seeds that corresponds to the day and species. Reference your handwritten data table for these numbers.

9. Column A, in the cell under the last day you entered, enter the words “germination rate.” A rate measures something over a period of time. You will calculate germination rate by using Excel to divide the number of seeds that germinated over the total number of days.

10. Then, in the cell next to the word “germination rate” (in column B) you will type a formula to determine the rate.
   a. First, type an “=” sign (do not use quotations)
   b. Then, click on the cell direction above (the number of seeds germinated on the last day). The cell number should appear next to the equal sign
   c. Then, enter a “/” to signify “divided by” (don’t use quotation marks)
   d. Then enter the total number of days you collected data for (in this case, enter 19)
   e. Then hit enter on the keyboard. You will likely get a decimal number. The number represents the amount of seeds that germinated each day.

11. Now, click on the cell that shows the germination rate. The cell should be highlighted. The bottom right corner of the cell should have a small black box.
a. Move the mouse over the little black box and a plus sign should appear
b. Then, hold your mouse down and drag the plus sign to the right, highlighting all a box under each of your species
c. Let go of the mouse. You should see the formula was filled in for all the other species.

12. Then, use the mouse to highlight the whole data set. And, click on Format on the options on the top of the screen. Under format, click on “cell,” then click “border” and click on “outline” and “inside.” Then, click ok. This will make a border around all your data.

13. Then, highlight cells B1 all the way across to the cell above the last species name in row 2. Click on Format, cells, and alignment. Then, check the box “merge cells.”

14. You can play with the font to improve the appearance of the data table.

15. Print the data table by highlighting your information. Then, under File, click “print area” and “set print area” Then print preview. If that is what you want, print the data table.

GRAPH

16. To graph the data, highlight all cells except for row 1 labeled “native species” and click on the chart wizard icon

17. Choose “Line” and click on next

18. Make sure the columns button is filled in, and press next

19. Then, fill in the title of the graph (from Part A. of this worksheet)

20. Fill in the x-axis label and unit

21. Fill in the y-axis label and unit

22. Click next and finish as “new sheet” and change the name “chart 1” to “Native species graph”

23. Print the graph

REPEAT THE STEPS FOR THE NON-NATIVE SPECIES DATA TABLE AND GRAPH
Appendix L: Results, Discussion, and Conclusion

Name: ________________

**Background**

Making hypothesis and collecting data is only part of a scientific investigation. Analyzing the data, drawing conclusions, looking at error, and asking NEW questions are the most important parts of an investigation. In college, my professors always told me “you can collect as much data as you want, but unless you analyze it and share it with other scientists, it is useless.” So, in order to make this germination experiment meaningful, we need to analyze the data.

So the task is not overwhelming, think of data analysis as a kind of reflection of what you learned from the data and the process. Do so by filling in the following chart.

<table>
<thead>
<tr>
<th>WHAT? (The Results Section)</th>
<th>SO WHAT? (The Discussion Section)</th>
</tr>
</thead>
<tbody>
<tr>
<td>State your results by explaining the data and the graphs in at least 6 sentences. What do the data show?</td>
<td>Analyze your results and discuss possible errors in at least 2 paragraphs. What do the data mean in relation to your research question and hypothesis?</td>
</tr>
</tbody>
</table>
NOW WHAT? (The Conclusion Section)
Relate your results to the big picture of competition between native and non-native species. How are these findings helpful to other scientists? At least 1 paragraph.

PEER REVIEW
Exchange your paper with another classmate. In the space below, the reviewer will write constructive and helpful comments for all sections. “Good” and “nice job” or anything similar to that is unacceptable and reviewers will not receive credit. BE AS HELPFUL AS POSSIBLE.
Reviewer’s name: __________________________

<table>
<thead>
<tr>
<th>Sections</th>
<th>Positive</th>
<th>Needs Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHAT?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SO WHAT?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WHAT NOW?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>