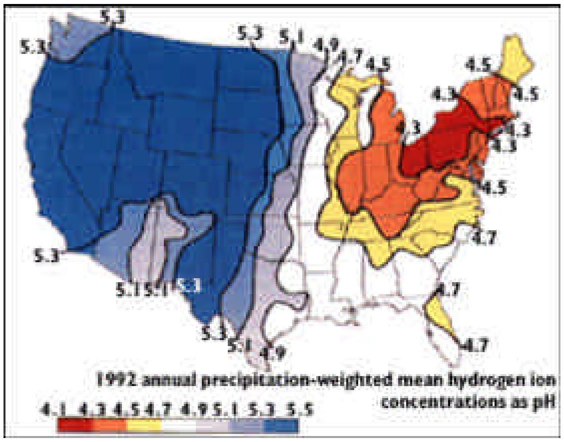
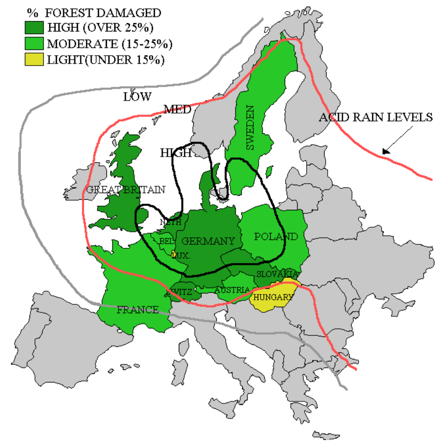
Acid Rain and Plant Growth

Introduction, general description of the phenomenon, why it is interesting and important

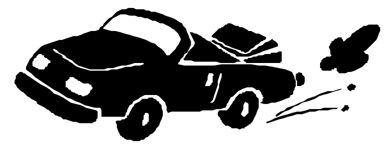




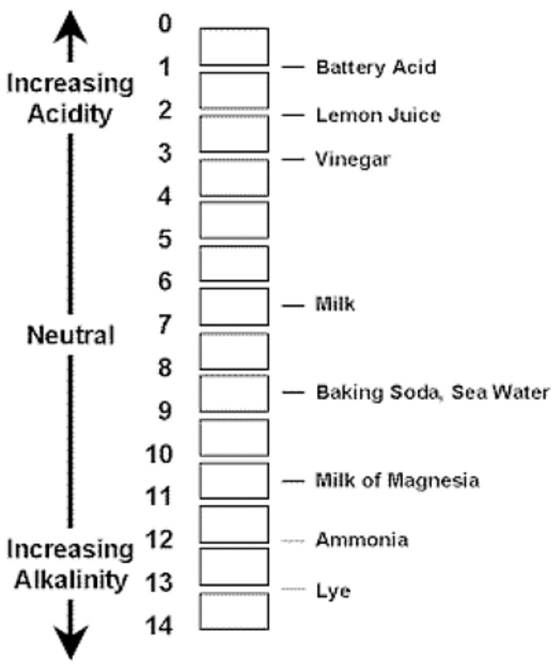
The term, 'acid rain' refers to a phenomenon in which falling rain sometimes can be acidic. This is a bad thing. Acid rain is a side-effect from the burning large amounts of fossil fuels like coal and petroleum, and usually occurs over regions downwind from clusters of large, modern, industrial cities. For example, acid rain falls in the northeastern part of the United States – downwind from the densely populated and heavily industrialized mid western states. It also is a problem in the European countries of Sweden and parts of Germany, downwind from the industrial centers of Great Britain, Belgium and Germany.

Acid rain is a bad problem because it can result in the death of plants and animals in lakes and streams. In some places, acid rain has been linked to the death of many trees, threatening whole forests.

The acids come from cars and fossil fuel- burning electrical power plants. Sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) are the two main pollutants in the exhaust smoke that cause the acid rain problem. They react with other substances in the atmosphere to make the acids found in acid rain. NO2 reacts to make nitric acid, and SO2 reacts to make sulfuric acid. Together, these acids dissolve in the water droplets that make up rain clouds where they change the chemical properties of the cloud itself, and eventually the rain that follows.



The term, 'acid,' is used by chemists to describe a kind of reactivity of a water solution. Strong acids are very reactive. Weak acids are weakly reactive and neutral solutions have no reactivity. Without getting into the chemistry itself, we can understand the significance of the 'reactivity' of water solutions. For example, grapefruit juice is moderately acidic. That is why you react so strongly after taking your first gulp. The same is true for cola soft drinks.



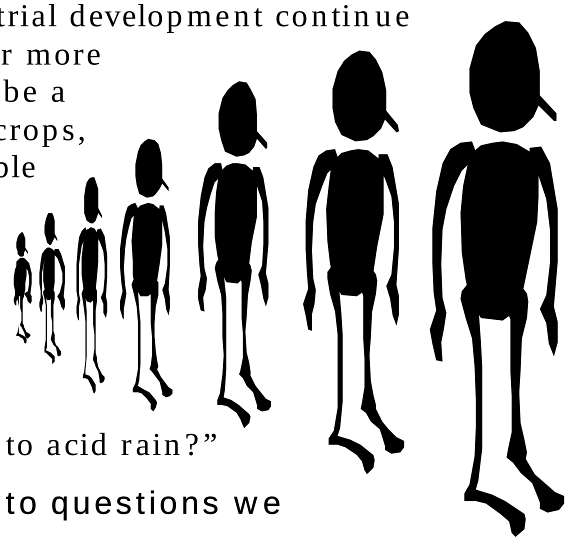
(SIDE NOTE: The term, 'basic,' refers to a similar but opposite kind of reactivity in water solutions. Soaps, detergents, and shampoos are very basic. That's why your eyes burn when you get shampoo in them. Ammonia also is very basic. That's why you get such a strong reaction after taking a big sniff on an ammonia bottle.)

The acids in the water solution cause the solution to become reactive. When an acid solution hits your tongue, it begins to chemically react with the cells on your tongue – and this causes sensory nerve cells to fire signals to your brain, notifying you of this fact.

Because acids are reactive, they interfere with the normal chemical processes that go on in living cells. Sometimes their level of interference is so disruptive that cells fail to properly execute their chemical duties. This action results in stress to the organism. If stress gets too great, or is prolonged, the organism could die.

Acid rain is an interesting and important environmental phenomenon, particularly considering its impact on natural ecosystems. But we are going to investigate another interesting concern related to the spread of acid rain – its potential to hurt agricultural crops.

As human population and industrial development continue to grow, so grows the potential for more widespread acid rain. Could this be a problem? If acid rain hurts food crops, it could mean that farmers are able to grow less and less food at a time when they need to be growing more and more food. Given the weight of these potential consequences, it is meaningful to ask the question…



"What will happen if agricultural plants are exposed to acid rain?"

How scientific thinking helps find out answers to questions we have about our natural world

Most of would agree that finding an answer to this question is meaningful and interesting. Since we are dealing with a phenomenon of the natural world, the best approach for finding stuff out in this arena is the 'scientific' approach.

Science is an intellectual tool independently invented / discovered by humans in different civilizations all over the world. Its primary application is for finding stuff out about natural reality.

The different stages of scientific discovery

In very general terms, scientific investigations start out simple, ignorant and weak. The goal is to make progress so that our understanding of the phenomenon in question becomes more sophisticated, more knowledgeable and more powerful. As the overall investigation continues, it builds on its past successes. Here is a list that briefly describes different stages of scientific discovery:

Observation / Descriptive Investigation

Answers the question, "What have we here?"

Controlled What-If Experiment

Answers the question, "What will happen if I introduce this single change?"

Explanation-Seeking Experiment

Answers the question, "What causes it to do that?"

Modeling What-If Experiment

Makes the prediction, "When introducing this change, the system will respond in this way."

Problem-Solving What-If Experiment

Acts on the statement, "I don't care how you do it, just fix it!"

The type of scientific investigation we will be conducting

Since we are asking the question, "What will happen if agricultural plants are exposed to acid rain?" the most appropriate type of scientific investigation is a 'Controlled What-If Experiment.'

This type of scientific investigation involves no hypothesis and no prediction. It is simply a fact-finding investigation. We are not seeking an explanation. Instead, we a 'fishing' for observations. But to make our observations as useful as possible, we need to setup our investigation as a controlled experiment.

The term, 'controlled experiment,' means an experiment in which all variables remain constant for all experimental subjects – except for a single variable. I our case, the acidity of the irrigation water is the single variable that will change. That way, we can see if significant growth differences are related to water acidity.

In addition, because we are just starting out in this potentially lengthy experimental study, our experiment will serve as a 'prototype.' That is, we are just testing the first of what could be many different experimental designs. It is very likely that despite our best efforts, our fist experiment will have many problems that will only reveal themselves during the conduct of the experiment – problems that cannot otherwise be predicted. We are doing empirical science here.

Project Mission

The mission of this project is to design, execute and evaluate the best possible, initial experimental investigation that can help us to answer the project's fundamental question.

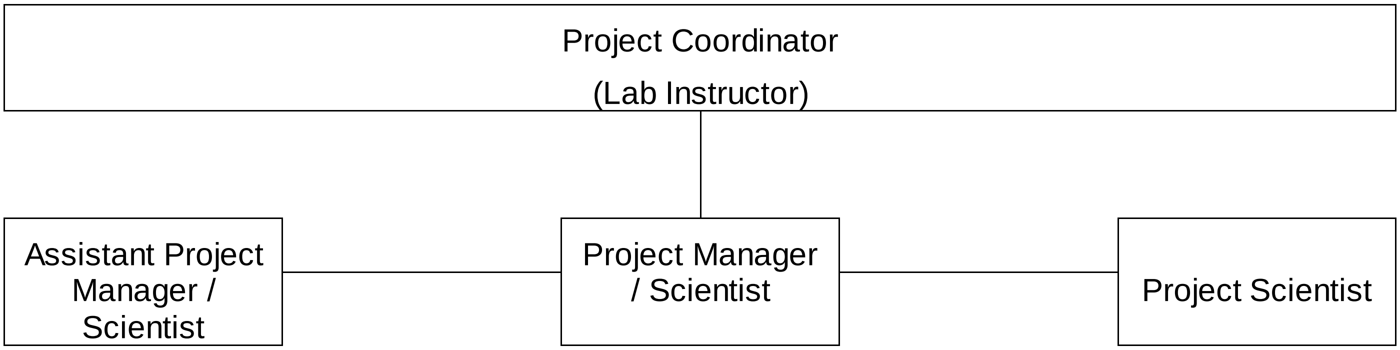
Given the complexity of the system and the inherent unpredictability of its outcome, we recognize that this investigation probably will not yield results of sufficient quality that we might confidently answer our question. In other words, this is a prototype experiment. As such, we are further obliged to evaluate all aspects of the investigation with the intent of designing more effective experiments to follow.

Project's expected outcomes

It is expected that most or all plants will germinate and grow throughout the experimental period. We expect that some plants exposed to acidic irrigation will experience stress but will otherwise continue to grow and express a generally healthy appearance.

We expect that at the end of the experimental period, we will have a population of plants of sufficient number and in sufficient states of health as to allow us to confidently evaluate the experimental design. In addition, we expect to be able to make some general predictions about the tendency for acids to be problematic or otherwise to our subject agricultural plants.

Project team organization



Project management and job assignments

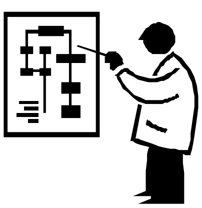
All members of the project team are expected to fulfill the role of team ‘scientist.’ And at least one member of the team must act as ‘project manger’ in addition to his / her ‘scientist’ duties.

Project Coordinator

The project coordinator ‘owns’ all projects. The project coordinator is responsible for supervising all project teams for the purpose of maximizing the chances for successful outcomes. The project coordinator may conduct weekly meetings with project managers for the purpose of identifying problems, keeping projects on track and dealing with personnel problems. The project coordinator may keep records of weekly meetings for later consultation during final project evaluations.

The project coordinator will assign grades to all team members based on the quality of project execution, the quality of submitted deliverables and in light of Team Evaluation forms.

Project Manager



The project manager will act as the person ‘IN CHARGE’ of the project. One person on the team will assume this role and the responsibilities that go with it.

The mission of the project manager is to oversee the project so as to increase its chances of success, and to eliminate its chances for failure. The responsibilities of the project manager include:

1. Being point of communication between the team and the project coordinator
2. Maintaining communication between all team members. Soliciting feedback regarding the status of the experiment and acting accordingly.
3. Supervising the proper and timely execution of the irrigation schedule
4. Supervising the proper and timely collection of experimental data

5. Solving problems that could jeopardize the success of the experiment. When possible, doing this following consultation with other team members.
6. Reporting personnel problems to the project coordinator.

Please note that the project manager is not to act as dictator / king. They do not OWN the project.

Assistant Project Manager

The assistant project manager will assume the project manager's duties if the project manager is absent or is not otherwise available.

Project Scientist

All members of the team are considered to be 'project scientists'. There are no 'pure managers' or pointy-haired bosses allowed. All members shall act in the capacity of project scientist during the course of the experiment.

The responsibilities of the project scientist include:

1. Full participation in the design and execution of the experiment
2. Frequent communication with the project manager and other team members
3. Identifying technical problems that could jeopardize the experiment and reporting to the project manager
4. Resolving project management problems with the project manager. In such cases where the scientist fails to reach equitable resolution, the scientist shall contact the project coordinator to seek necessary remedies.

Project's experimental design – prototype

Design An Experiment: Working in groups, design an experiment to answer the project's fundamental question, using laboratory resources I will make available to you. Write down your design and critique it until you are satisfied with it.

Time Frame: The experiment will start on the day of the first lab meeting and will end on the day of the last lab meeting.

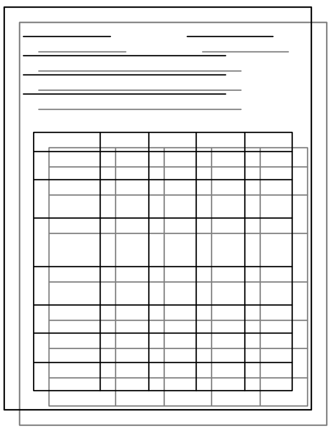
Equipment: Write down all the equipment you are going to use and all the procedures you are going to follow.

Control: Do you have a *control group* with which to compare experimental results? Your design should consist of two major groups of plants; 1) control group and; 2) experimental group(s).

The control group is intended to be the reference group to which the experimental groups will be compared. Generally, the control group is set up to simulate natural, or normal conditions. Each experimental group should be identical to the control group except for a single, experimental factor. It is important that only a *single* factor be different in the experimental group. Why?

Analysis: RIGHT NOW, figure out how you are going to evaluate your results. What are you going to measure? How will you use these accumulated numbers? Will you average them? Will you look for rates of growth? What kind of quantitative and qualitative comparisons can you perform? **DO THIS NOW**.

***Quality* Control:** Before settling on a final experimental design, try to identify any possible problems with your methods. Are your control and experimental groups clearly identifiable? Do your experimental groups differ from your control group by only one factor? Have you eliminated all potential sources of human-caused artifacts which might, in themselves, affect plant growth and so, confuse your results?



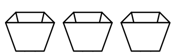
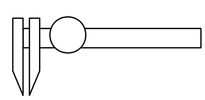
Data Collection: Design and prepare a data collection form. This graphical representation can better help you to understand your experiment and identify any bugs in your thinking. Include spots on the form for tracking the progress of your different groups. A good data collection form helps simplify the data collection process over the term of the experiment.

Team Organization And Work Schedule: Prepare and complete a schedule to indicate who is doing what when. List project team members and their titles.

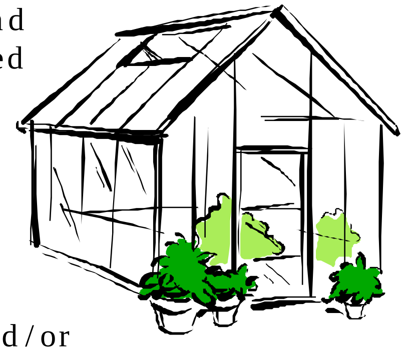
When your group is satisfied with a procedure, check with the **project coordinator** before going to work.

Available Materials

The following materials should be available to you.

1. Seeds (species may vary)
2. pH meter, and pH paper
3. 4" Pots 
4. metric rulers
5. Calipers – for measuring stem thickness 
6. Potting soil
7. graduated beakers – for measuring irrigation amounts 
8. Three kinds of pre-mixed irrigation solutions
    a. Sulfuric acid solution (pH 3)
    b. Sulfuric acid solution (pH 5)
    c. Tap water (pH 7)
9. environmental chamber / greenhouse

Gaining Access To The Greenhouse



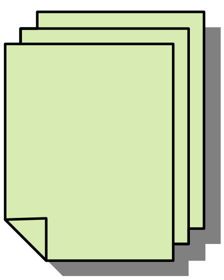
The greenhouse is located in the Native Plant garden adjacent to and east of the 600 building. The garden and greenhouse are kept locked when not in use. If you need to get into the greenhouse during times when we are not meeting in lab, you will need to borrow a key. A key is available in the mailbox of Tom Morris located in the first floor lobby area of the 400 building. It is your responsibility to actively coordinate your irrigation schedule so as to ensure access to the greenhouse.

The key will be made available only for the time needed to water and/or observe your plants. Please lock the greenhouse and garden gate when you are done, and immediately return the key to Tom Morris's mailbox.

What you will be turning in and how you will be evaluated

Each Team

At the minimum, **each project team** will be expected to submit the following items to the project coordinator at a time determined by the project coordinator:



Report of Findings – to include:

1. Two pages of text that conforms to the Report of Findings Format
2. Copies of all raw data collection sheets
3. Copies of the final work schedule showing who did what and when – including how each team member contributed to the preparation of the report of findings.

Evaluation of Your Results: In evaluating the results of your acid rain experiment, consider the following issues:

1. Was your experiment successful? (How do you define the term, 'successful,' in this case?)
2. How reliable are your results? (How much money would you bet that your results are useful and meaningful?)
3. Were there flaws in your experimental design?
4. In planning and executing your experiment, you had to make assumptions about how things should be and how things should go. How good were your assumptions?
5. What were the sources of error and artifact in the execution of your experiment? (Did you or anyone else unintentionally disturb your experimental subjects in ways that might alter the outcome?)
6. Can you establish a statistically significant trend in the effects of acids on your plants? (Why can your team NOT perform a useful statistical analysis on your results?)

7. How must the concept / knowledge of "Optimum Growing Conditions" influence your experimental design? (You should be seeking the clearest signal possible from your subjects – with a minimum of interference.)
8. Think of all the specific ways you would re-investigate the issues of acid rain and its effects on your subject plant. (Based on what you have learned from this experiment, how would you refine the design and execution of your experiment?)

Web links

http://www.econet.apc.org/acidrain/

http://bqs.usgs.gov/acidrain/

http://bqs.usgs.gov/precip/arfs.htm

http://pubs.usgs.gov/gip/acidrain/2.html

http://www.epa.gov/airmarkets/acidrain/

http://www.necc.mass.edu/MRVIS/MR1_6/start.htm

http://www.ec.gc.ca/acidrain/

http://www.ns.ec.gc.ca/msc/as/as_acid.html

http://maize.agron.iastate.edu/corngrows.html

http://www.nebraskacorn.org/